KNIGHTS FERRY GRAVEL REPLENISHMENT PROJECT

Work Authority # 1469-8520, Project # 97-N21

TASK 4 CONSTRUCTION REPORT

Prepared for

CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

Prepared by

Carl Mesick Consultants
7981 Crystal Boulevard
El Dorado, California 95623
Phone/Fax: (530) 620-3631
cmcfish@innercite.com

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INTRODUCTION

The purpose of the Knights Ferry Gravel Replenishment Project is to improve the quantity and quality of spawning habitat for fall-run chinook salmon (*Oncorhynchus tshawytscha)* at 18 riffles in the lower Stanislaus River near Knights Ferry and to evaluate different methods of restoring spawning habitat. Most of the project riffles are located in Stanislaus County except for the uppermost site in Goodwin Canyon which is located on the border between Tuolumne and Calaveras counties. The Stanislaus River is a tributary to the San Joaquin River.

Several studies indicate that spawning habitat in the Stanislaus River has limited the production of fall-run chinook salmon. Studies funded by the Stockton East Water District (CMC et al. 1996) indicate that most (77%) chinook salmon in the Stanislaus River restrict their spawning to the areas upstream of the riffle's crest where the streambed rises sharply ($\geq$ 2% gradient). Most of the 120 riffles in the spawning reach between Goodwin Dam and Riverbank have low crests, which minimizes the downwelling of surface flow (Dahm and Valett 1996), and they are heavily laden with sand and silt. A study by the Department of Water Resources (1994) indicated that the percentage of fines in substrate samples taken just upstream of the riffle's crest was unsuitable for the incubation of chinook salmon eggs at 45% (ten) of their study riffles located between Goodwin Dam and Riverbank.

Carl Mesick Consultants (CMC et al. 1996; CMC 1997) determined that intragravel conditions are degraded by the inflow of oxygen-poor groundwater, an effect that temporarily worsens after heavy rainstorms. In fall 1995, approximately 20% of the sites had suboptimal dissolved oxygen concentrations (50% to 80% of saturation) and another 15% had lethal dissolved oxygen concentrations (<50% of saturation). After several heavy rain storms in January 1996, the number of sites with lethal dissolved oxygen concentrations increased to 42%. Most of the sites with unsuitably low dissolved oxygen concentrations occurred downstream of the riffle's crests, which were the areas avoided by most of the spawners.

The lack of silt-free gravel in the Stanislaus' spawning reach is primarily caused by inadequate gravel recruitment, encroachment of riparian vegetation in the floodplain which accelerates the flushing of gravel during high flows, and a high concentration of suspended sediments in storm runoff. Gravel recruitment to the spawning reach is blocked by the upstream reservoirs and the problem is aggravated by past instream gravel mining and by captured mine pits such as the Willms Site (rivermile 52). Riparian encroachment has become worse since the construction of New Melones Reservoir in 1980 which essentially eliminated flooding. The thick riparian growth along the riverbanks of the Stanislaus River increases shear stress within the channel during moderate to high flows such that gravel is mobilized at abnormally high rates. Compared to the 1960s when the Department of Fish and Game made extensive channel measurements (Department of Fish and Game 1972), the channel has now doubled in width and is still widening. In addition, the Stanislaus River is quite incised compared to the Tuolumne and Merced rivers. Suspended sediments are another problem that begins in the upstream areas at Owl Creek (rivermile 57.5) and gradually worsens in a downstream direction during rainstorms.

PROJECT DESCRIPTION

To improve chinook salmon spawning habitat, clean spawning-sized gravel was added to 18 existing spawning riffles scattered throughout 17 miles of the lower Stanislaus River between

Two-Mile-Bar and the City of Oakdale (Figures 1-5). Adding clean spawning gravel to existing spawning riffles should improve survival and emergence of incubating salmon eggs by improving intragravel flow. A high rate of intragravel flow improves egg survival by delivering high concentrations of dissolved oxygen and by flushing away poisonous waste products. It also minimizes entombment of alevins by minimizing the amount of fines dispersed during redd construction that are subsequently deposited on downstream redds.

Another purpose of this project is to evaluate different methods of restoring spawning habitat. One issue to be addressed is why the spawning habitat project implemented in 1994 in the Stanislaus River under the Four Pumps Agreement were utilized by few spawning salmonids. A study conducted by Carl Mesick Consultants (CMC et al. 1996) indicated that for the first three years after the Four Pumps Stanislaus Project restoration was completed, chinook salmon would spawn immediately adjacent to but not within the newly added gravel even though intragravel conditions in the new gravel were quite suitable for spawning. Then during the fourth year after construction, spawner use greatly increased at one of the project sites after high flows deposited natural Stanislaus gravel on top of the restoration gravel. Possible explanations for why the fish avoided the restoration gravel include (1) the added rock came from the Merced River; (2) most of the rock was angular in shape which would make it difficult for the salmon to excavate redds; and (3) very little of the added rock was less than ½ inch. By comparing spawner use of the various sources and sizes of gravel added with spawner use at the control riffles, this project will evaluate the effect of source and size of gravel.

An evaluation will also be made as to whether the natural streambed configuration, particularly the height of the riffle's crest, affects spawner use and project longevity. Most of the riffles in the majority of the Stanislaus' spawning reach are low gradient and occur in incised channels which may make them difficult to restore. This project will evaluate the feasibility of improving the low gradient riffles compared to the high gradient riffles. Comparisons will also be made between this project's design of adding gravel at an existing riffle's crest versus the past Four-Pumps Project designs that excavated the streambed to create flat riffles (<0.5% gradient).

Pre-project monitoring of chinook salmon habitat was conducted in fall 1998 to monitor spawner use and intragravel water conditions and was completed in August 1999 when gravel samples, substrate permeabilities, and streambed elevations were measured. Post-project habitat monitoring will occur in fall 1999 and fall 2000.

Construction

Prior to gravel placement, gravel was stockpiled at each of the project riffles at locations designated by the U.S. Army Corps of Engineers and the other property owners from February through September 1999. Eight project riffles were accessed through U.S. Army Corps of Engineer's (ACOE) fee property, seven were accessed through both ACOE and three private landowners, and another three were accessed through private property. There are existing roads within 25 meters of the riverbed at all project sites.

A total of 13,000 tons of washed gravel were added to the 18 project riffles (Table 1) between 4 August 1999 and 24 September 1999. To study different restoration techniques, the project riffles were divided into three groups that differed according to the height of the natural riffle's crest (a.k.a. the hydraulic control). One group of six riffles has high crests formed by the sharply

upsloping tails of pools where the streambed gradient is at least 4%. Between 300 and 860 tons of gravel were added to the undisturbed streambed immediately upstream of the crests of five of the riffles in this group, whereas 1,430 tons were placed at Riffle R14A which is an old inriver gravel mining pit. The second group of riffles has moderate crests with a 2 to 4% streambed gradient. Between 330 to 1,200 tons of gravel were added to the undisturbed streambed immediately upstream of the crests of the riffles in this group. At the moderate- and high-crested riffle sites, the added gravel raised the elevation of the existing crest by an average of 0.85 feet and up to a maximum of 2 feet at Riffle R19A. The last group of six riffles has low crests that rise at a streambed gradient of less than 2%. Between 440 and 900 tons of gravel were added to the undisturbed streambed to raise the riffle's crest by an average of 1.1 feet and up to a maximum of 2 feet at Riffle R57. At all project riffles, gravel was added to make the riffle's crest a uniform elevation across the width of the river, perpendicular to the streamflow. This should maximize the downwelling of surface flow into the gravel and help stabilize the new streambed.

Three types of gravel were added to the 18 project riffles for the purposes of the study (Table 1). One type consisted of rounded river-rock from the Stanislaus' floodplain that has a natural mixture of 1/4 to 5 inch diameter rock. Originally, a 1/8 inch mesh screen was to be used to clean this mixture rather than a 1/4 inch mesh; however, the 1/8 inch screen was frequently clogged with sand making it impossible to clean the gravel. Even with mechanical agitation and a high pressure water spray, the 1/4 inch mesh screen clogged frequently and much of the gravel in this mixture had to be processed twice. A grizzly with five inch spacing between the bars was used to exclude large rocks. A second type of gravel consisted of Stanislaus river-rock with a natural mixture of 3/8 to 5 inch rock. All Stanislaus River gravel was obtained from the Ohe Gravel Quarry, which is adjacent to riffles R14 and R14A. The third type consisted of a natural mixture of 3/8 to 5 inch diameter river-rock obtained from the 7-11 Materials gravel quarry on the Tuolumne River. The Tuolumne river-rock was placed only at riffles where spawner use has been relatively low from 1994 through 1998 to ensure that spawner use did not decline as a result of this project. Crushed rock was not used at any project site. Each type of gravel was be added to six project riffles, two from each of the high-, medium-, and low-crested riffle groups. This design provided two replicates for each combination of gravel-gradient type.

The plan to use an articulated hauler with a load capacity of 30 tons to transport 7,980 tons of gravel from the Ohe Gravel Quarry across the river at riffles R14 and R14A to seven nearby riffles was not implemented. Gravel processing and placement was delayed by the permitting process and unusually high flows until mid summer when gravel demand was high, and the managers at the Ohe Gravel Quarry were unwilling to stockpile the 7,980 tons of gravel at their plant until the hauler could be used in September. Therefore, all gravel was transported over county roads with 21-ton end-dump haulers and the additional 1,500 tons of gravel was not obtained as mitigation for use of the articulated hauler. The haulers were first steam cleaned to remove any oil from the truck's bed before the gravel was hauled.

A front-end loader with rubber tires and a bucket capable of carrying six-tons of gravel (Photo 1 and report cover) was used to transport the gravel from the stockpile to the river and then grade it to design specifications at all sites except Riffle R78. The hydraulic hoses and engine gaskets on the front-end loader were replaced immediately prior to construction to minimize leakage of hydraulic fluid and oil. During gravel placement, water was sprayed on the gravel stockpile to wash away fines that had accumulated since the gravel had been stockpiled (Photo 2). Grading

Photo 1: Front-End Loader grading the gravel at Riffle R1, Stanislaus River, 9/8/99.

Photo 2: Washing the stockpiled gravel at Riffle R29, Stanislaus River, 8/10/99.

was done by lowering the bucket onto the gravel and driving the loader in reverse to drag the gravel. To minimize the inconvenience to rafters, a "lookout" was posted to delay work in the river whenever boaters were within 100 yards upstream or downstream of the crossing site.

At Riffle R78, 570 tons of gravel were added using a hydraulic pump with an eight-inch diameter hose (Photo 3). The hydraulic pump was placed on an existing road within 40 feet of the water's edge so that water could be re-circulated from the river to transport the gravel through the hose. A front-end loader was used to feed the gravel into a hopper that had a five-inch grizzly on top to exclude rocks that would clog the hose (Photo 4). Water was continuously pumped through an open chamber in the bottom of the hopper to flush the gravel into the hose to the riverbed. A flexible section of hose and a directional nozzle were used to help direct gravel placement. The 570 tons of gravel were placed in about 28 hours using the hydraulic pump. A small bulldozer was used to finish the gravel grading at this site.

The project sites were cleaned, dirt roads regraded, and additional cleanup work performed as requested by the property owners after the gravel had been placed. Copies of the "Project Completion Notice" from the U.S. Army Corps of Engineers and a "Mitigation Work List" of additional work done for the Army Corps are included after the literature cited.

Gravel hauling and placement was performed by Joe Cover & Sons, Inc., 19290 Cherokee Road, Tuolumne, California 95379 under subcontract to Esquivel Grading & Paving Inc., 1210 Armstrong Avenue, San Francisco, California 94124. The work was jointly supervised by Mr. Sean Smith with Esquivel Grading and Paving and Dr. Carl Mesick.

Mapping

Contour maps of the streambeds at each of the project sites were made with a Nikon DTM-310 total station before and after the gravel was added. The DTM-310 has an angle accuracy of five seconds, which provides elevation measurements accurate to within 0.03 inches at a distance of 100 feet. The elevation data were collected as X, Y, Z coordinates, stored electronically within the total station, and then downloaded to a laptop computer. A software program called "Transit" was then used to convert the data into AutoCAD DXF format files. The DXF files were then imported into a software program called Terrain Tools/98 - Version 3.044 to generate the contour maps in one-foot intervals. Two 18-inch metal stakes were driven into the ground during the pre-project survey and a third was added during the post-project survey to provide backsites with fixed elevations. The elevations of the tops of the backsites were measured during each survey. The total station was set to an elevation of 4.77 feet at each site for the pre-project survey. To facilitate comparisons between the pre- and post-construction surveys, all elevation data collected for the post-construction survey were uniformly adjusted so that the height of the backsites matched the backsite heights measured during the pre-construction surveys. At some sites it was not possible to survey the river's edge on the side where the total station was set due to extensive riparian vegetation that completely blocked the view of bank. Elevation data were collected at five-foot intervals along transects established in November 1998 and September 1999 and elsewhere in a grid pattern in approximately 15-foot intervals. New transects were established in September 1999 only when the November 1998 transect did not pass over the newly placed gravel. The boundaries of the new gravel beds were also surveyed in September 1999. Streamflows ranged between 500 cfs and 600 cfs during the pre-construction survey and they were 375 cfs during the post-construction survey. Measurements with the stadia

Photo 3: Hopper and pumps used to place gravel at Riffle R78, Stanislaus River, August 1999.

Photo 4: Gravel pumping through 8-inch diameter hoses at Riffle 78,
Stanislaus River, August 1999

rod and prism were made using a raft tethered to a rope stretched across the river at portions of a majority of the riffles during the pre-construction surveys.

The contour maps of the riffles before and after gravel placement are shown in Figures 6 through 39. The one-foot contour intervals do not show that the gravel was placed to create a continuous upward slope from the upstream boundary to about midway to the downstream boundary. Typically, the gradient of the upward slope was at least 1.5 percent, which is a rise of about one-half foot moving over a distance of 30 feet in a downstream direction across the riffle. This upward slope reproduced the configuration found in tails of pools that is preferred by spawning salmon. Presumably the upward slope is preferred by salmon because it creates moderate water velocities compared to downward sloping riffle surfaces and it enhances the downwelling of surface water into the gravel.

REFERENCES CITED

Carl Mesick Consultants, Aquatic Systems Research, and Thomas R. Payne & Associates. 1996. Spawning habitat limitations for fall-run chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank. Draft report prepared for the Stockton East Water District and Neumiller and Beardslee.

Carl Mesick Consultants. 1997. A fall 1996 study of spawning habitat limitations for fall-run chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank. Draft report prepared for the Stockton East Water District and Neumiller and Beardslee.

Dahm, C.M. and H.M. Valett. 1996. Chapter 6, Hyporheic Zones. Pages 107 through 119 *in* F.R. Haur and G.A.Lamberti, editors. Methods in Stream Ecology. Academic Press.

Department of Fish and Game. 1972. Report to the California State Water Resources Control Board on effects of the New Melones Project on Fish and Wildlife Resources of the Stanislaus River and Sacramento-San Joaquin Delta. Jointly produced by Region 4 in Fresno, Anadromous Fisheries Branch in Sacramento, Bay-Delta Research Study in Stockton, and the Environmental Services Branch in Sacramento in October 1972.

Department of Water Resources. 1994. San Joaquin River tributaries spawning gravel assessment: Stanislaus, Tuolumne, Merced rivers. Draft memorandum prepared by the Department of Water Resources, Northern District for the California Department of Fish and Game. Contract number DWR 165037

Project Completion Notice

Knights Ferry Gravel Replenishment Project

Esquivel Grading and Paving has performed satisfactory site cleanup work on US Army Corps property for the above referenced project.

Phillip Holcomb
Park Manager
US Army Corps of Engineers Representative

9/30/99
Date

MITIGATION WORK FOR THE U.S. ARMY CORPS OF ENGINEERS

For The

Knights Ferry Gravel Replenishment Project

Valley Oak Recreation Area (Riffles R57 and R58)

1. Trenched about 400 feet for irrigation lines as per Ranger Jason Anderson

2. Removed a 40-foot diameter clump of *Arundo donax* and placed in burn pile.

3. Removed timbers and steel cap footings and placed along side of trail.

Orange Blossom Recreation Area (Riffle R43)

4. Removed four concrete footing slabs from an old flood damaged bridge from the river.

Horseshoe Recreation Area (Riffle R28A)

5. Excavated and brushed a 60 foot by 30 foot river frontage as per Ranger Dave and Ranger Jason Anderson.

Western Sand and Gravel (Riffles R12A - R19A)

6. Removed flood debris, i.e., submerged and mangled steel culvert pipe, from center of river.

Russian Rapids Portage Trail (Riffle R5)

7. Improved an Army Corps road by installing a culvert and a drain field with cobble stones where a spring flowed across the road and then graveled about 100 yards of the road.

Knights Ferry Recreation Area (Riffle R1)

8. Removed four submerged timber pilings below the bridge that were a hazard to rafters and replaced stranded gravel from a mid channel island back into the channel to reform the riffle immediately downstream of the bridge (Riffle R2).

Table 1. Project and control riffles selected for the Knights Ferry Gravel Replenishment Project. A total of 13,000 tons of gravel were placed at 18 project riffles: 4,490 tons of Stanislaus river-rock 1/4 to 5 inch; 5,570 tons of Stanislaus river-rock 3/8 to 5 inch; and 2,940 tons of Tuolumne river-rock 3/8 to 5 inch. The seven control riffles were not altered. Western Sand and Gravel, Ms. Frymire, and Mr. Mangante were the private landowners that provided river access to some riffles.

A) High-Crested Riffles (Tails of Deep Pools), 4 to 14% Streambed Gradient					
Riffle #	Rivermile	Gravel Type	Tons	Cubic Yd	Access
TMA	56.8	Stanislaus River-Rock, 1/4 to 5 inch diameter	840	470	Two-Mile-Bar: Mr. Mangante
TM1	56.6	Control Riffle, No Gravel Added	--	--	Two-Mile-Bar: ACOE
R1	54.55	Stanislaus River-Rock, 3/8 to 5 inch diameter	550	395	Knights Ferry Bridge: ACOE
R12	53.3	Control Riffle, No Gravel Added	--	--	Ms. Nancy Frymire
R14A	52.57	Stanislaus River-Rock, 3/8 to 5 inch diameter	1,430	1,055	Ohe Gravel Quarry
R15	52.51	Tuolumne River-Rock, 3/8 to 5 inch diameter	860	610	Lovers Leap Reach: ACOE & WSG
R28A	50.2	Stanislaus River-Rock, 1/4 to 5 inch diameter	450	250	ACOE Horseshoe Road Park
R29	49.75	Tuolumne River-Rock, 3/8 to 5 inch diameter	300	210	ACOE Honolulu Park
R76	40.35	Control Riffle, No Gravel Added	--	--	ACOE Oakdale Recreational Park
B) Moderate-Crested Riffles, 2 to 4% Streambed Gradient					
Riffle #	Rivermile	Gravel Type	Tons	Cubic Yd	Access
R10	53.5	Control Riffle, No Gravel Added	--	--	ACOE & The Hunter's Ranch
R13	52.73	Stanislaus River-Rock, 3/8 to 5 inch diameter	1,200	860	Lovers Leap Reach ACOE & WSG
R14	52.6	Stanislaus River-Rock, 1/4 to 5 inch diameter	835	465	Ohe Gravel Quarry
R16	52.48	Tuolumne River-Rock, 3/8 to 5 inch diameter	330	240	Lovers Leap Reach: ACOE & WSG
R19A	52.06	Stanislaus River-Rock, 3/8 to 5 inch diameter	950	680	Lovers Leap Reach: ACOE & WSG
R27	50.8	Control Riffle, No Gravel Added	--	--	ACOE Horseshoe Road Park
R58	44.5	Stanislaus River-Rock, 1/4 to 5 inch diameter	840	465	ACOE Valley Oak Park
R78	40.2	Tuolumne River-Rock, 3/8 to 5 inch diameter	570	405	ACOE Oakdale Recreational Park

ACOE = U.S. Army Corps of Engineer's Fee Property; WS&G = Western Sand & Gravel

Table 1. Continued.

C) Low-Crested Riffles, 0 to 1.4% Streambed Gradient					
Riffle #	Rivermile	Gravel Type	Tons	Cubic Yd	Access
R5	53.9	Tuolumne River-Rock, 3/8 to 5 inch diameter	440	315	ACOE Russian Rapids Portage
R12A	52.82	Stanislaus River-Rock, 3/8 to 5 inch diameter	540	380	ACOE, WSG, & Ms. Nancy Frymire
R12B	52.77	Stanislaus River-Rock, 1/4 to 5 inch diameter	850	470	ACOE WSG, & Ms. Nancy Frymire
R19	52.13	Stanislaus River-Rock, 1/4 to 5 inch diameter	675	130	Lovers Leap Reach: ACOE & WSG
R20	51.8	Control Riffle, No Gravel Added	--	--	Lovers Leap Reach: ACOE & WSG
R43	46.9	Tuolumne River-Rock, 3/8 to 5 inch diameter	440	315	ACOE Orange Blossom Bridge Park
R57	44.6	Stanislaus River-Rock, 3/8 to 5 inch diameter	900	645	ACOE Valley Oak Park
R59	44.4	Control Riffle, No Gravel Added	--	--	ACOE Valley Oak Park

ACOE = U.S. Army Corps of Engineer's Fee Property; WS&G = Western Sand & Gravel;

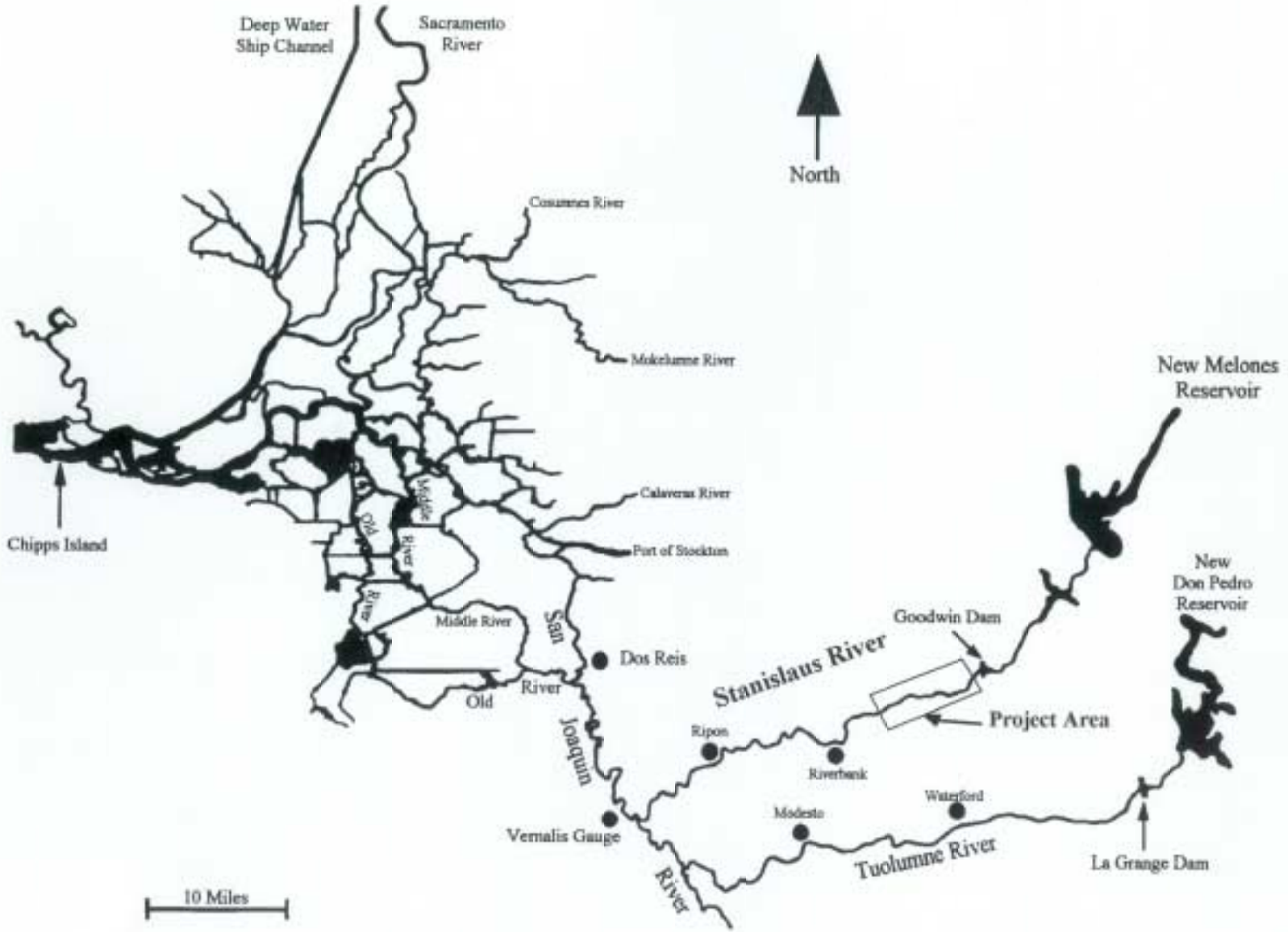

Figure 1. Map of the Sacramento-San Joaquin Delta showing the Stanislaus River, Goodwin Dam, and the project area from Two-Mile-Bar to Oakdale.

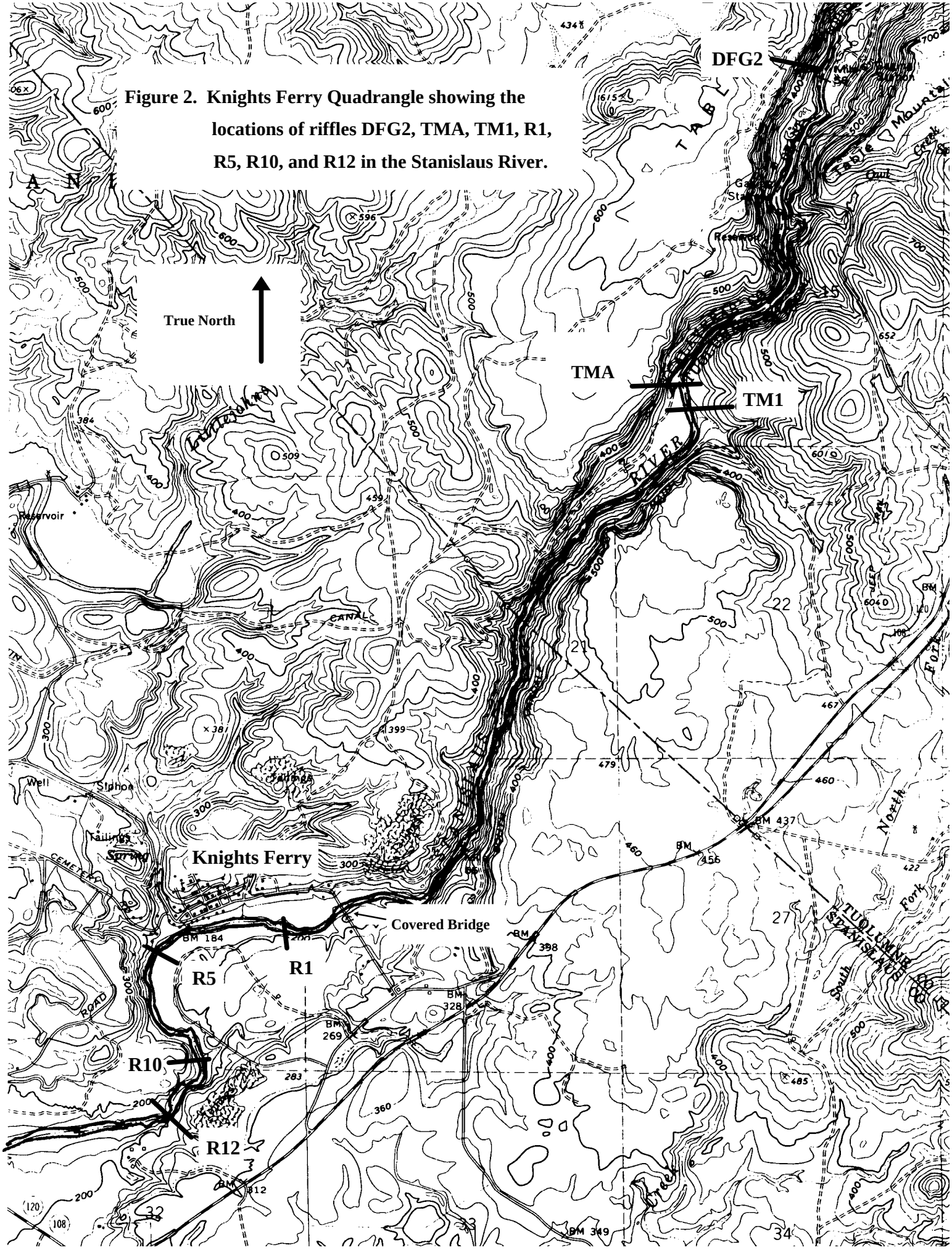

Figure 2. Knights Ferry Quadrangle showing the locations of riffles DFG2, TMA, TM1, R1, R5, R10, and R12 in the Stanislaus River.

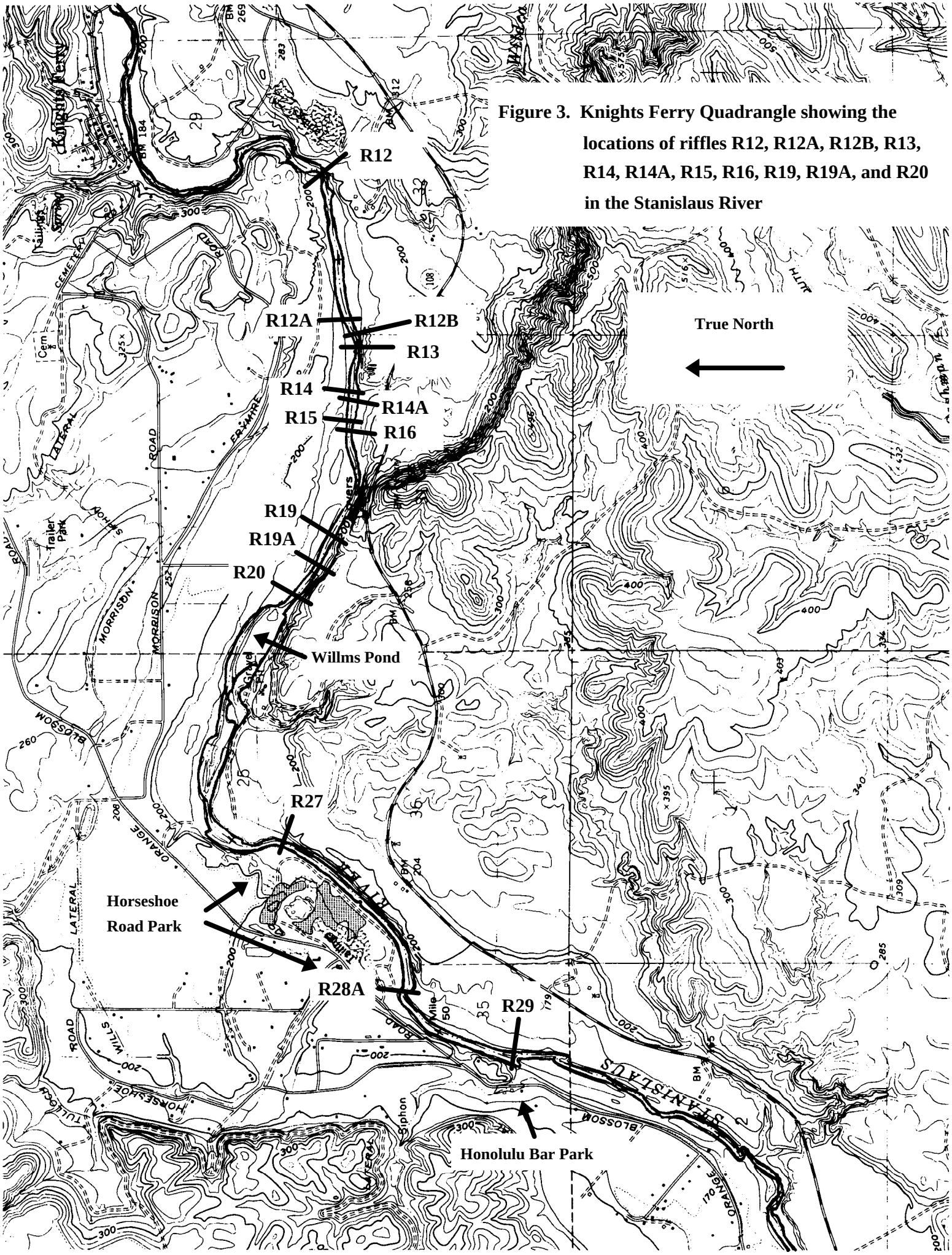

Figure 3. Knights Ferry Quadrangle showing the locations of riffles R12, R12A, R12B, R13, R14, R14A, R15, R16, R19, R19A, and R20 in the Stanislaus River

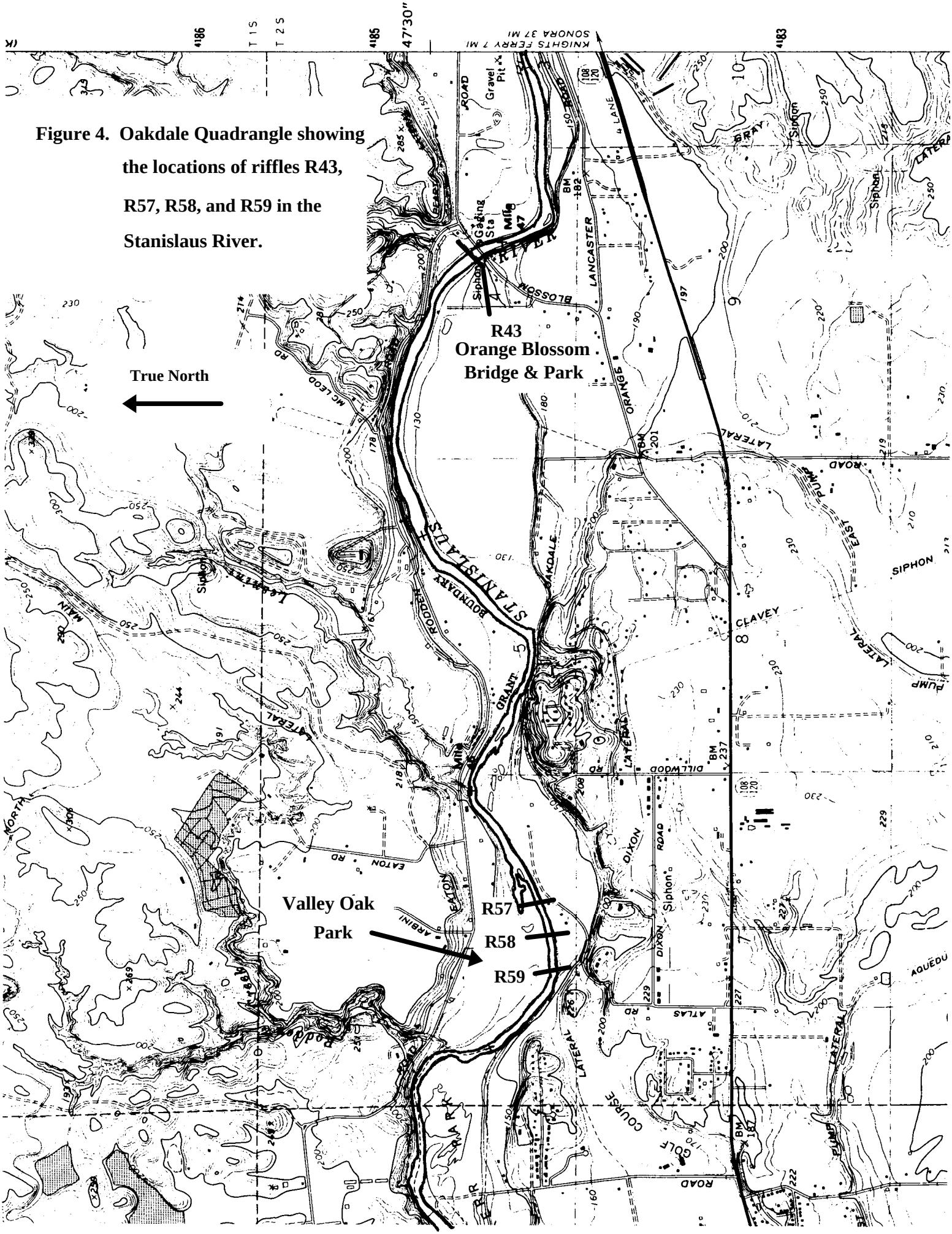

Figure 4. Oakdale Quadrangle showing the locations of riffles R43, R57, R58, and R59 in the Stanislaus River.

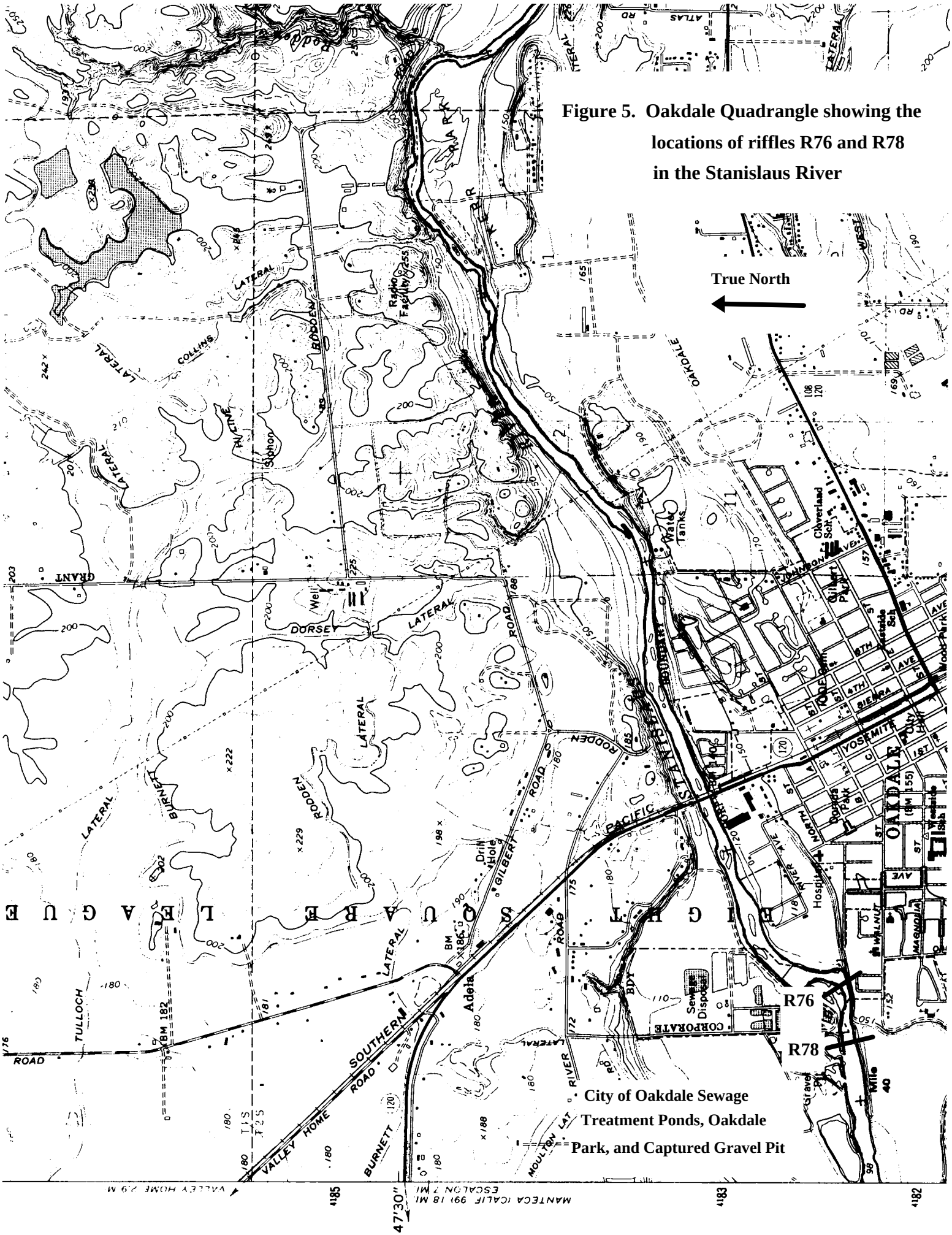

Figure 5. Oakdale Quadrangle showing the locations of riffles R76 and R78 in the Stanislaus River

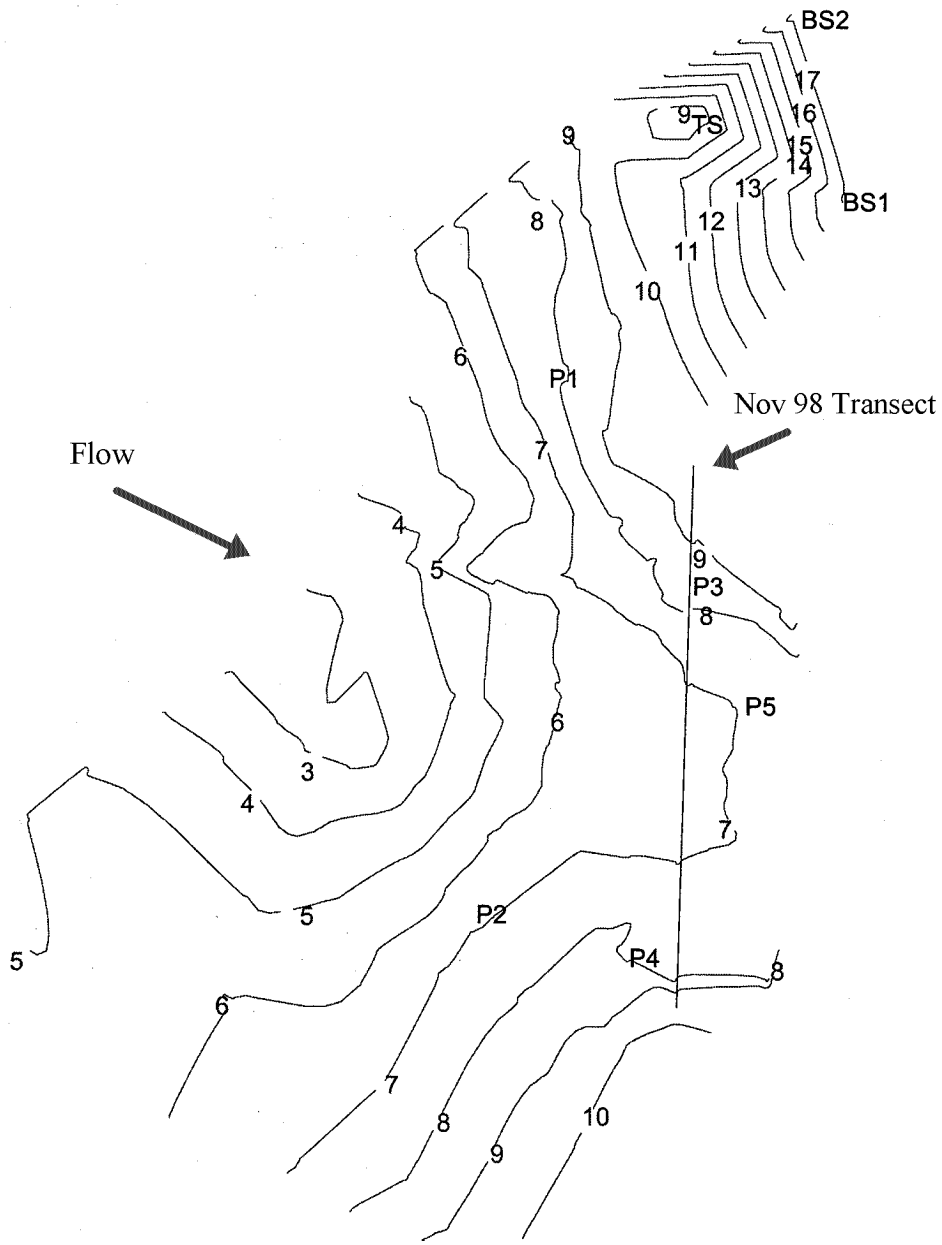

Figure 6. Contour map of Riffle TMA at rivermile 56.8 on the Stanislaus River on 4 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equal 41.7 feet. The water surface elevation was about 9.9 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 17.05 feet and at back site 2 (BS2) is at 17.53 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P5.

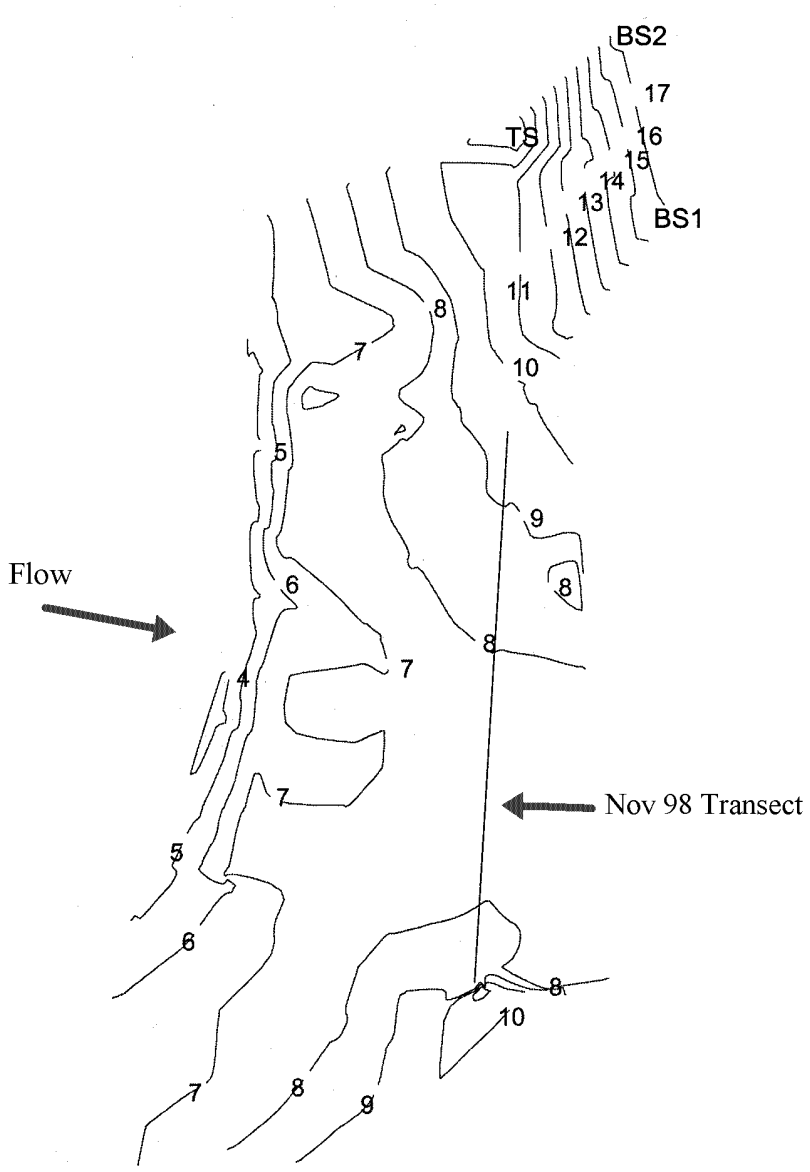

Figure 7. Contour map of Riffle TMA at rivermile 56.8 on the Stanislaus River on 24 August 1999, which was after 840 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equal 41.7 feet. The water surface elevation was about 9.7 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 17.05 feet and at back site 2 (BS2) is at 17.53 feet.

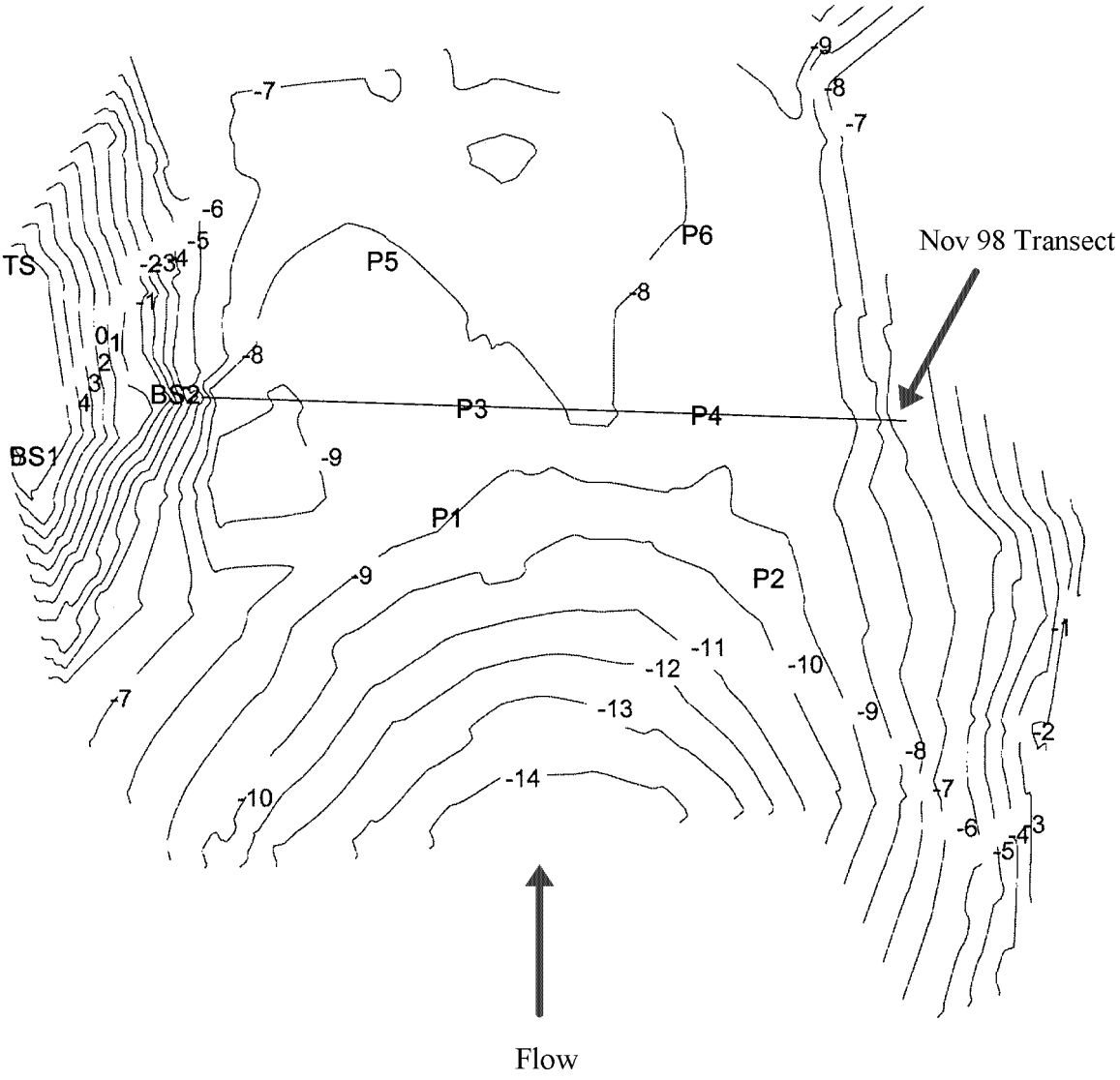

Figure 8. Contour map of Riffle R1 at rivermile 54.6 on the Stanislaus River on 3 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -6.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.01 feet and at back site 2 (BS2) is -1.07 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P6.

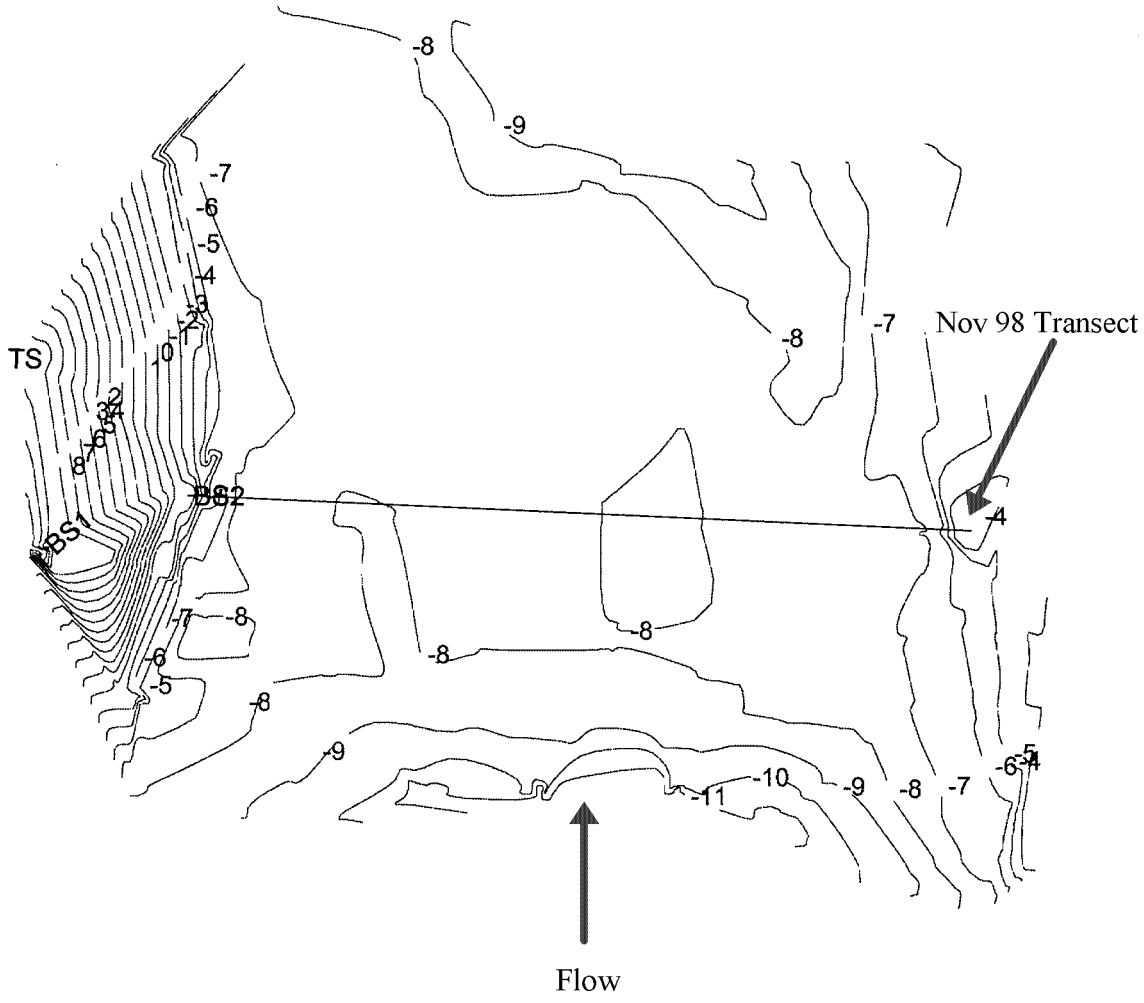

Figure 9. Contour map of Riffle R1 at rivermile 54.6 on the Stanislaus River on 20 September 1999, which was after 550 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -6.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.01 feet and at back site 2 (BS2) is -1.07 feet.

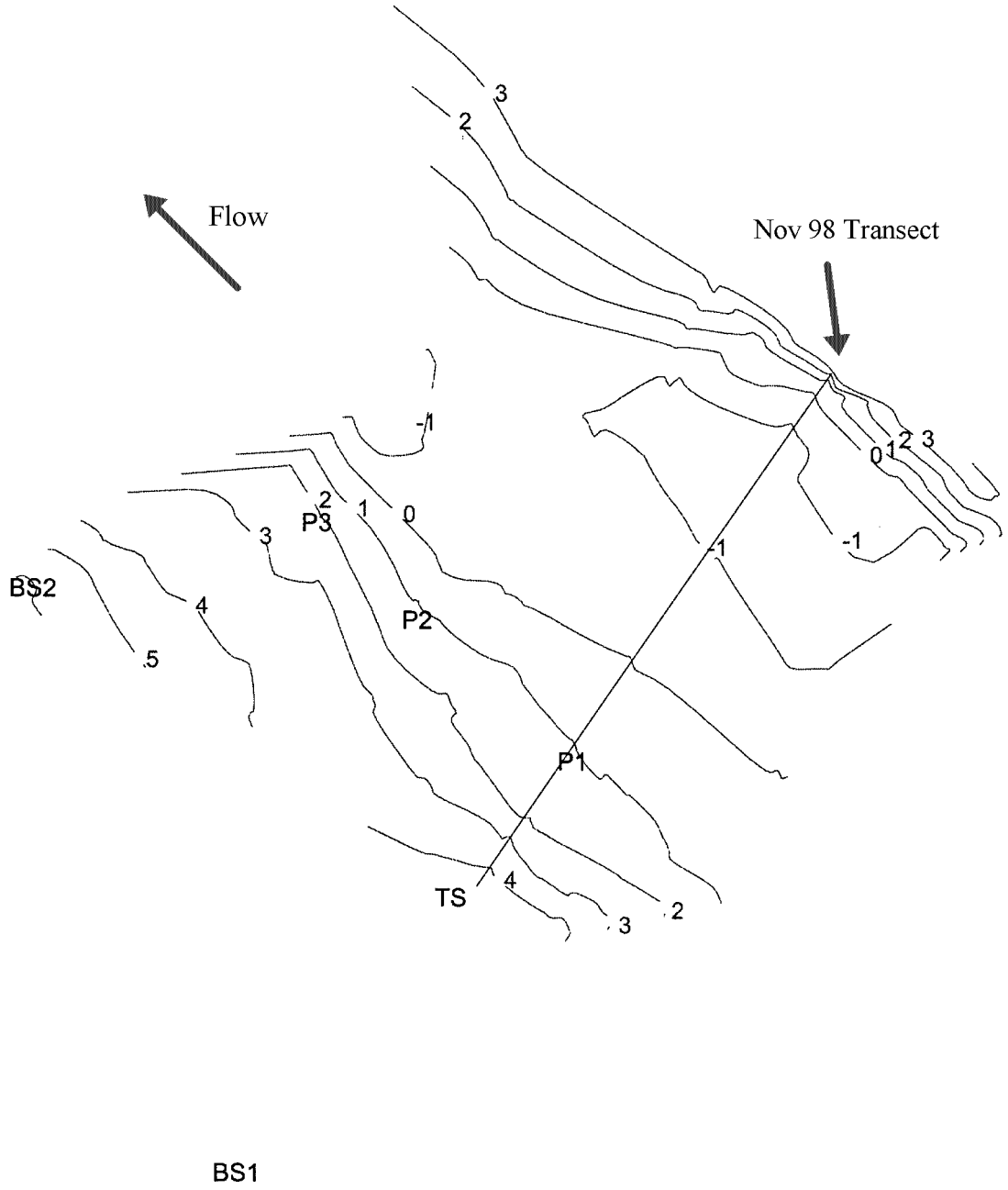

Figure 10. Contour map of Riffle R5 at rivermile 53.9 on the Stanislaus River on 5 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 3.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.11 feet and at back site 2 (BS2) is 6.25 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P3.

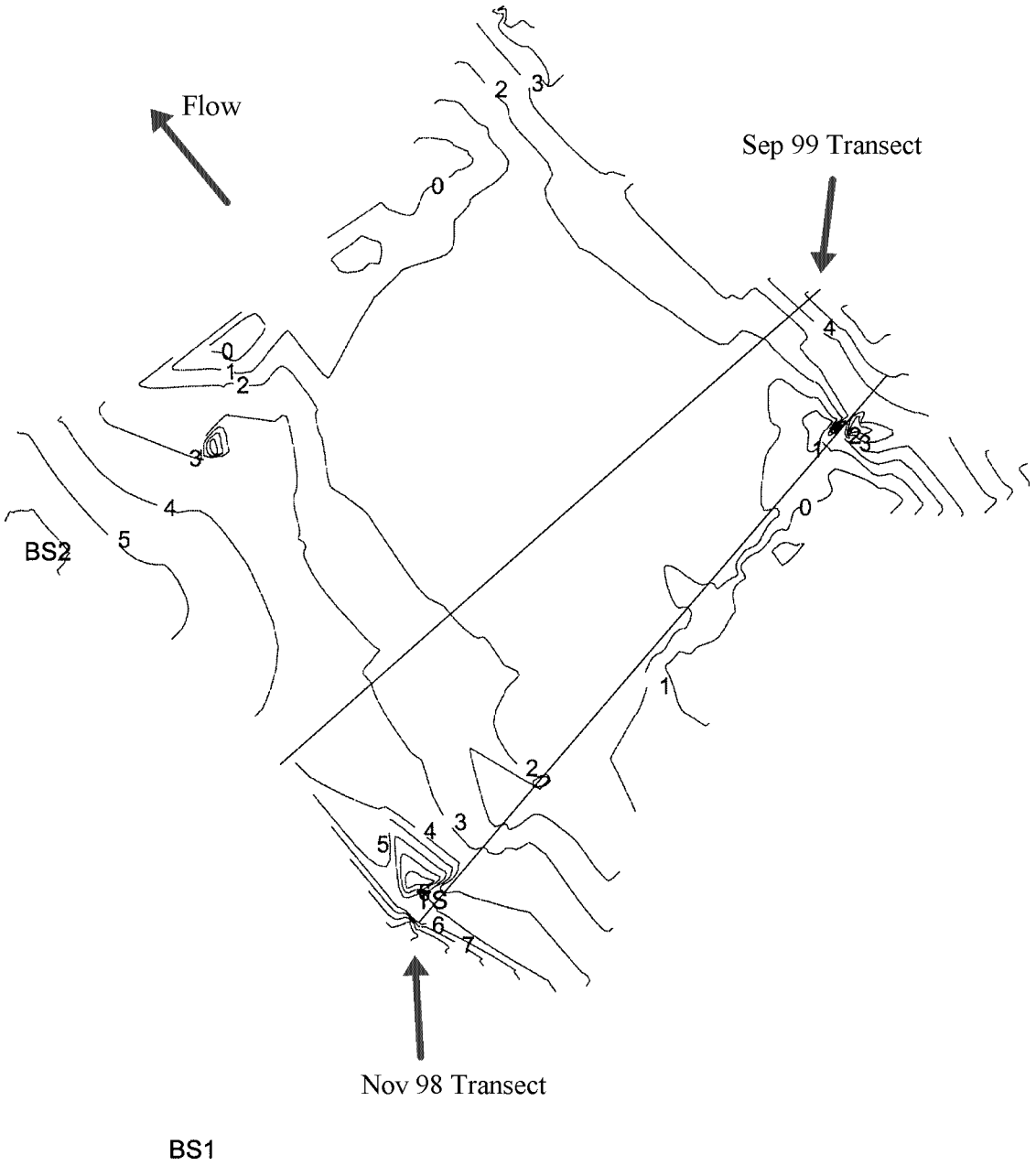

Figure 11. Contour map of Riffle R5 at rivermile 53.9 on the Stanislaus River on 20 September 1999, which was after 440 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 3.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.11 feet and at back site 2 (BS2) is 6.25 feet.

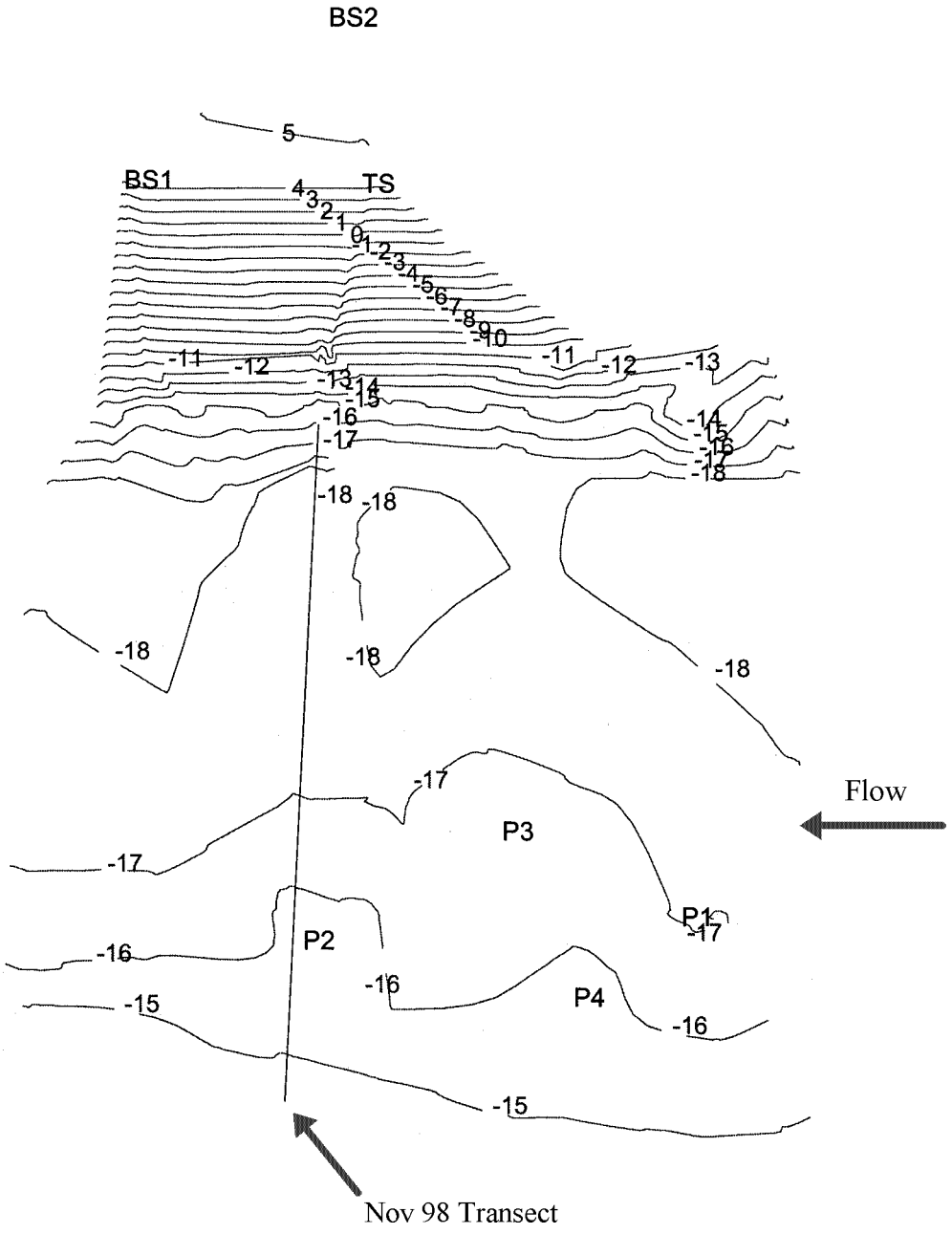

Figure 12. Contour map of Riffle R12A at rivermile 52.8 on the Stanislaus River on 11 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -14.5 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 4.51 feet and at back site 2 (BS2) is 5.87 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P3.

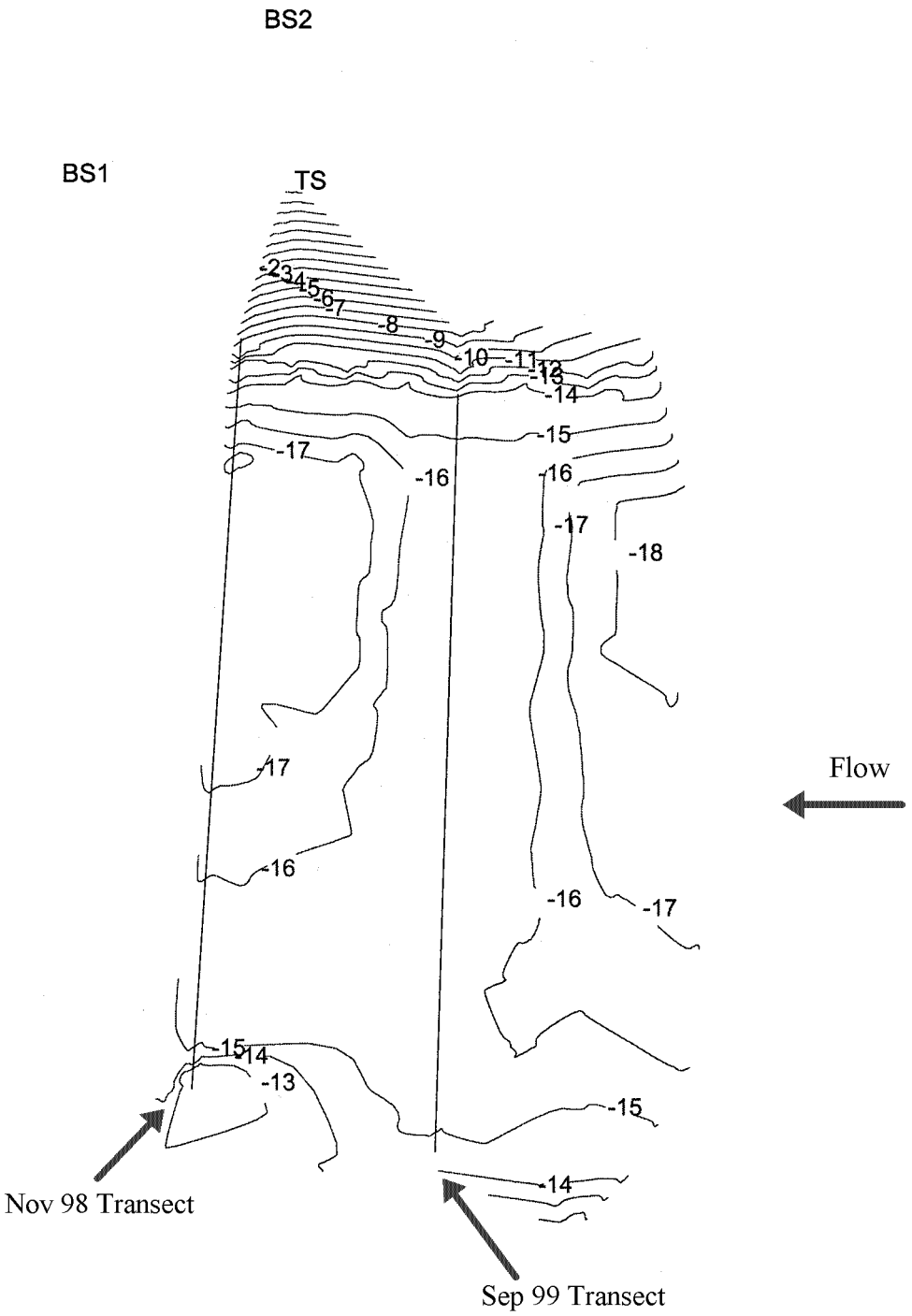

Figure 13. Contour map of Riffle R12A at rivermile 52.8 on the Stanislaus River on 21 September 1999, which was after 540 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -14.5 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 4.51 feet and at back site 2 (BS2) is 5.87 feet.

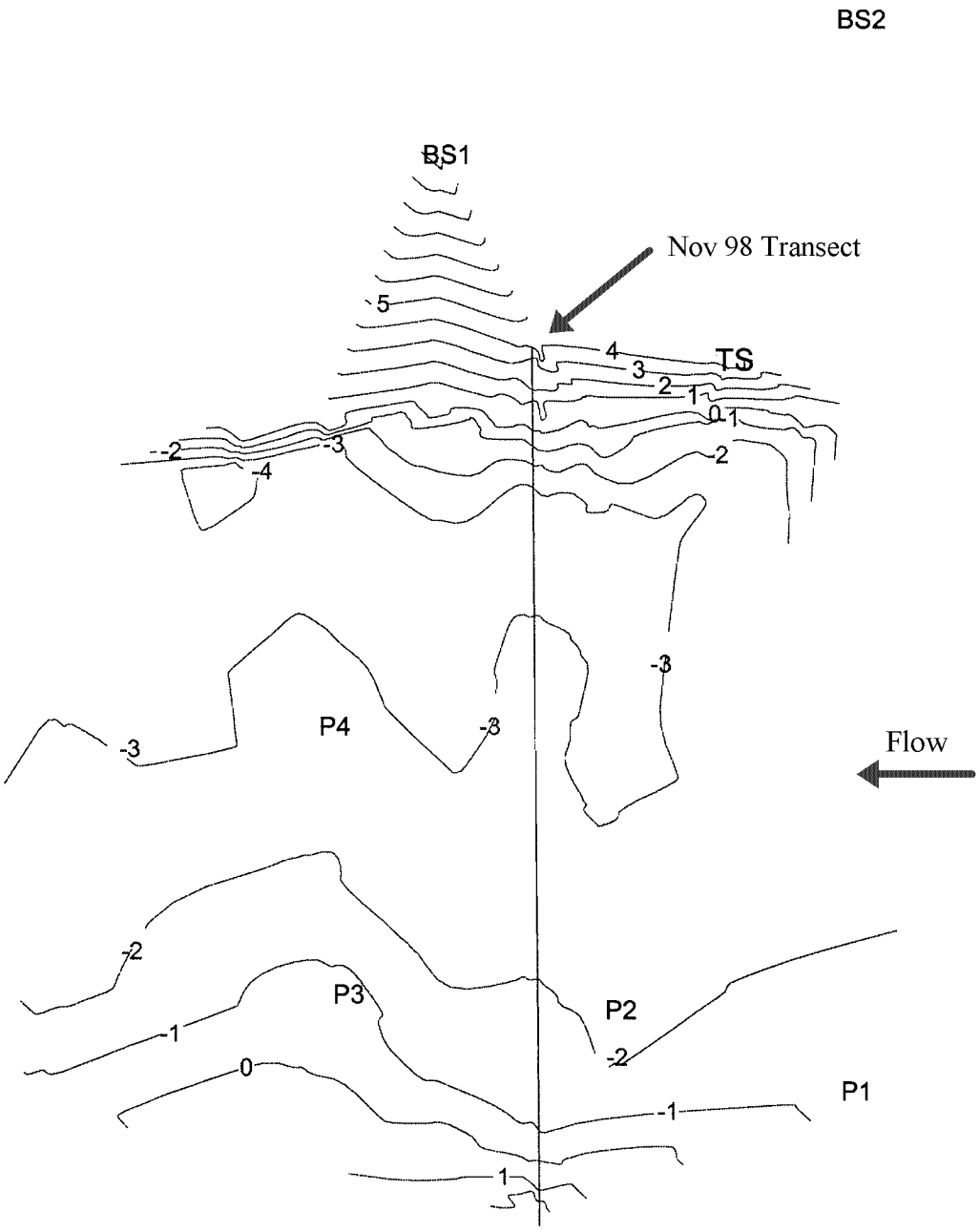

Figure 14. Contour map of Riffle R12B at rivermile 52.77 on the Stanislaus River on 11 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 0.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 11.07 feet and at back site 2 (BS2) is 19.84 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P4.

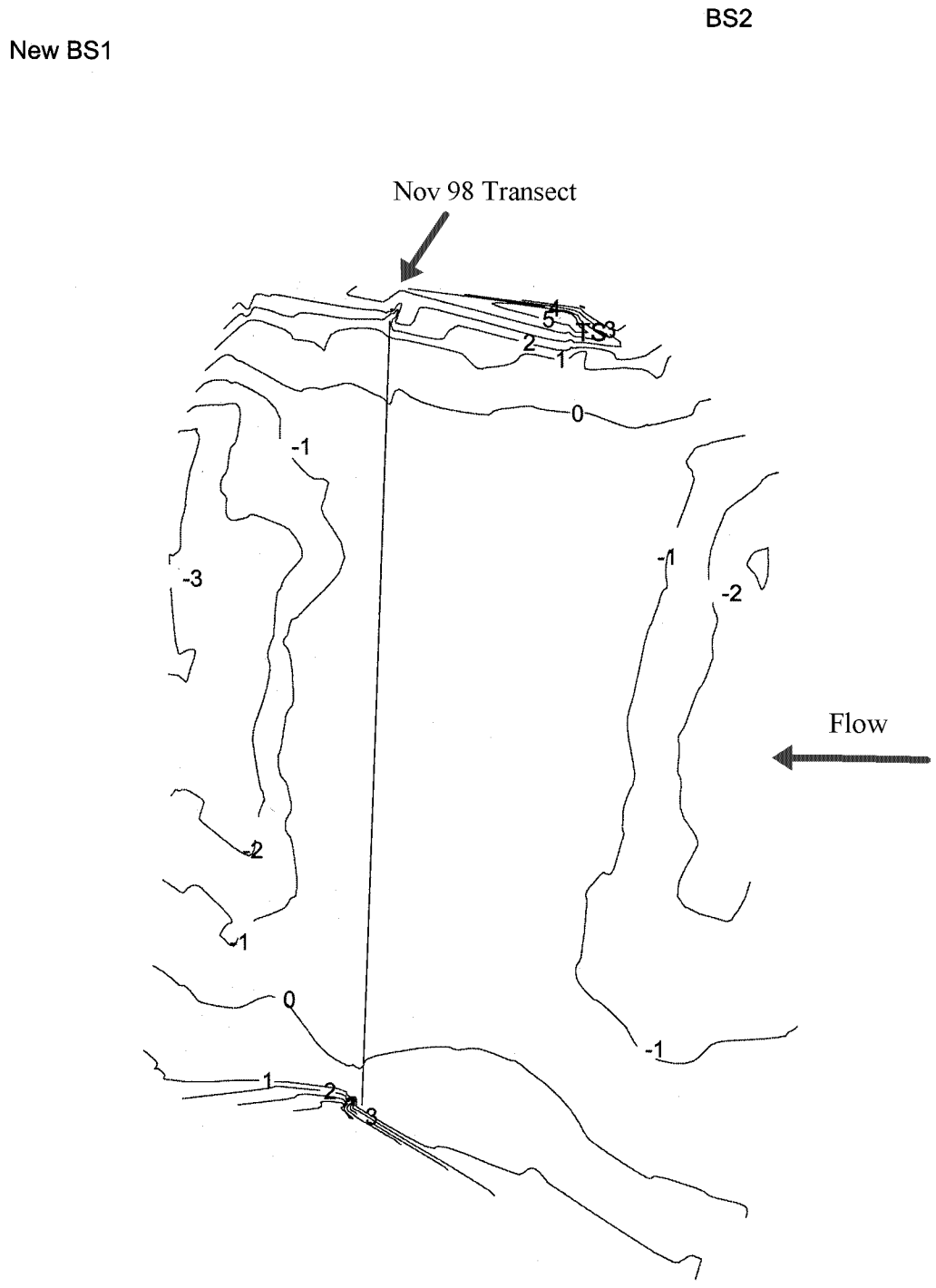

Figure 15. Contour map of Riffle R12B at rivermile 52.77 on the Stanislaus River on 21 September 1999, which was after 850 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 0.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at the new back site 1 (BS1) is 10.36 feet and at back site 2 (BS2) is 19.84 feet.

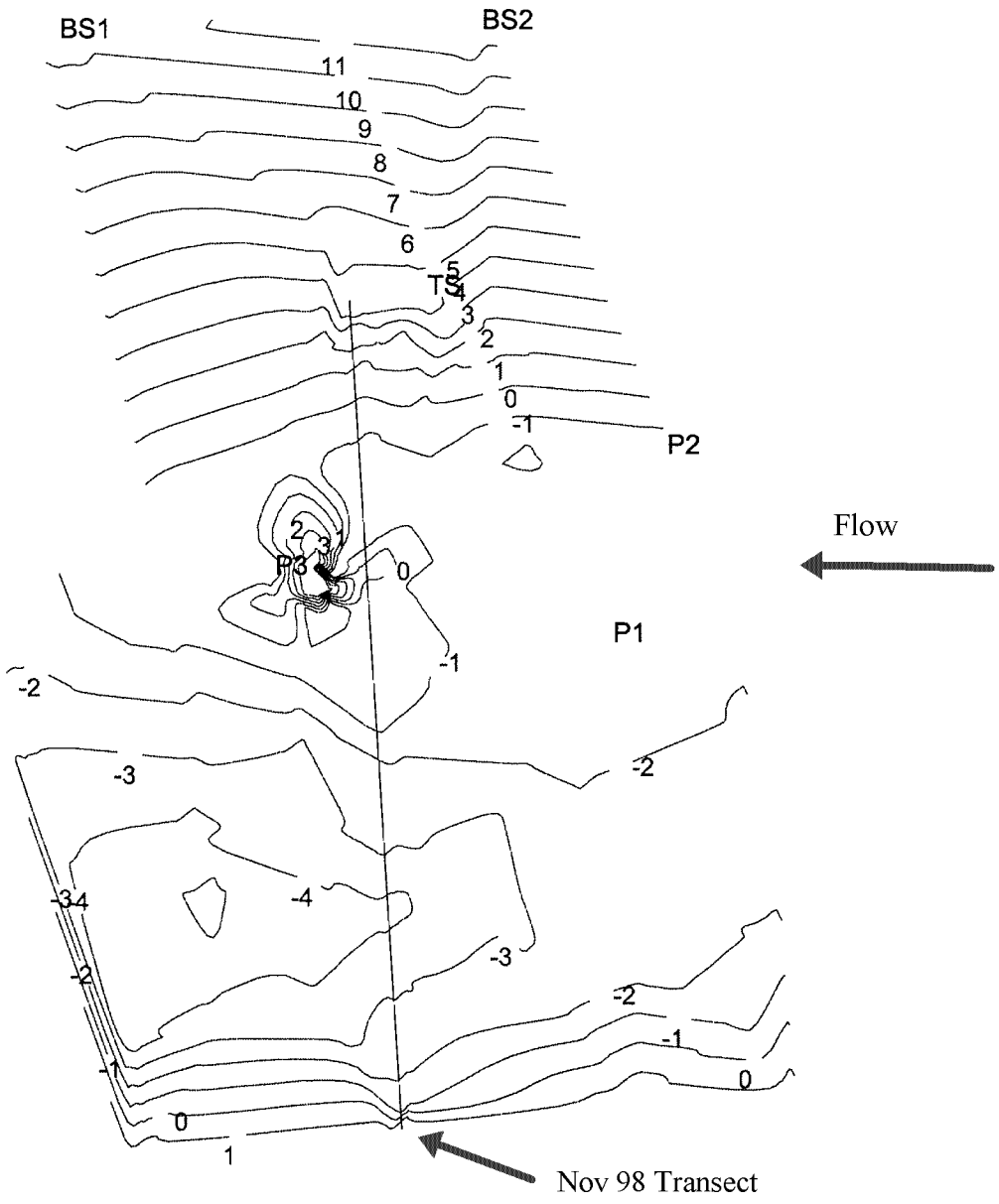

Figure 16. Contour map of Riffle R13 at rivermile 52.73 on the Stanislaus River on 12 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 1.7 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 10.57 feet and at back site 2 (BS2) is 11.76 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P3.

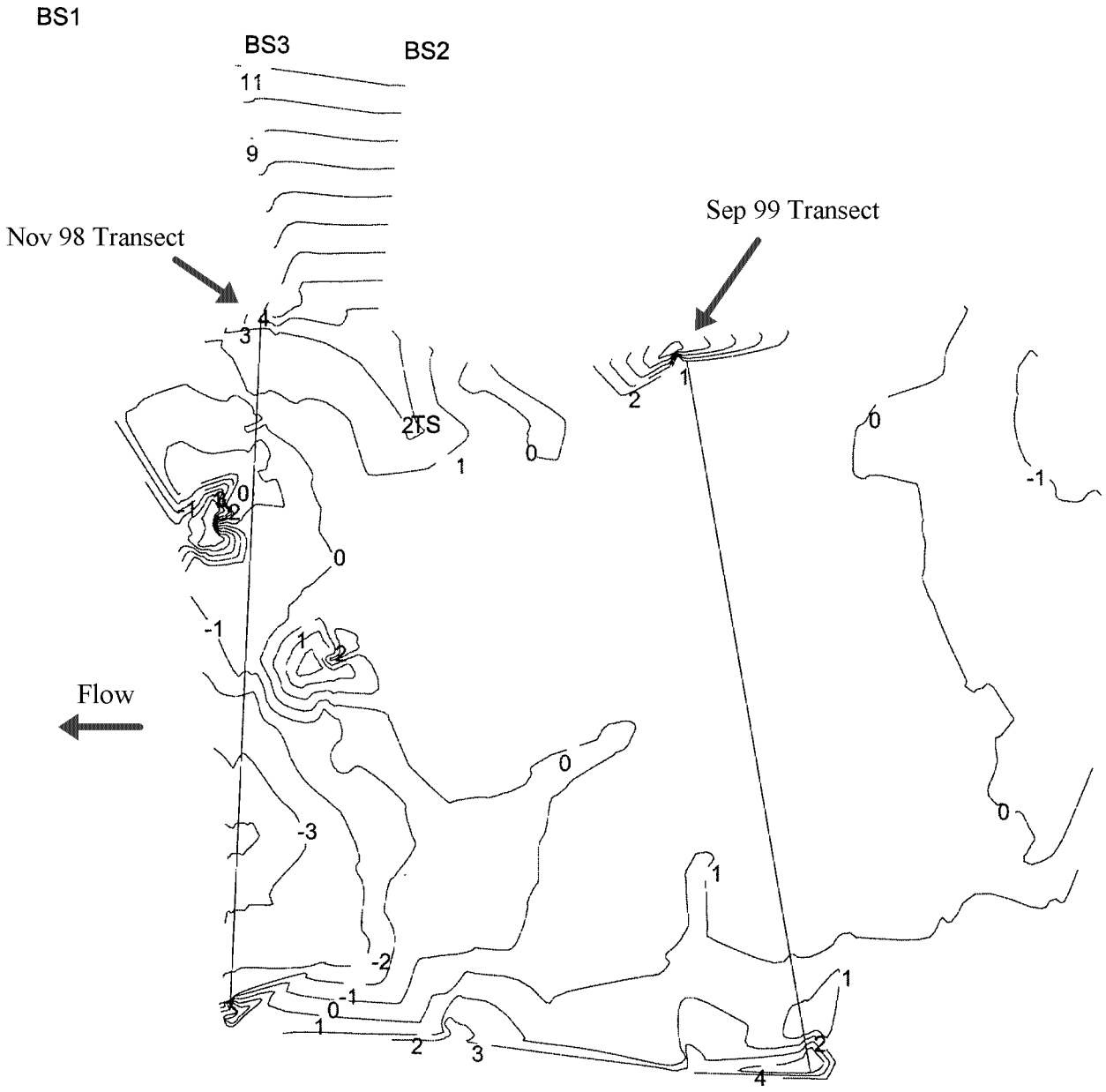

Figure 17. Contour map of Riffle R13 at rivermile 52.73 on the Stanislaus River on 22 September 1999, which was after 1,200 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 1.7 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 10.57 feet and at back site 2 (BS2) is 11.76 feet.

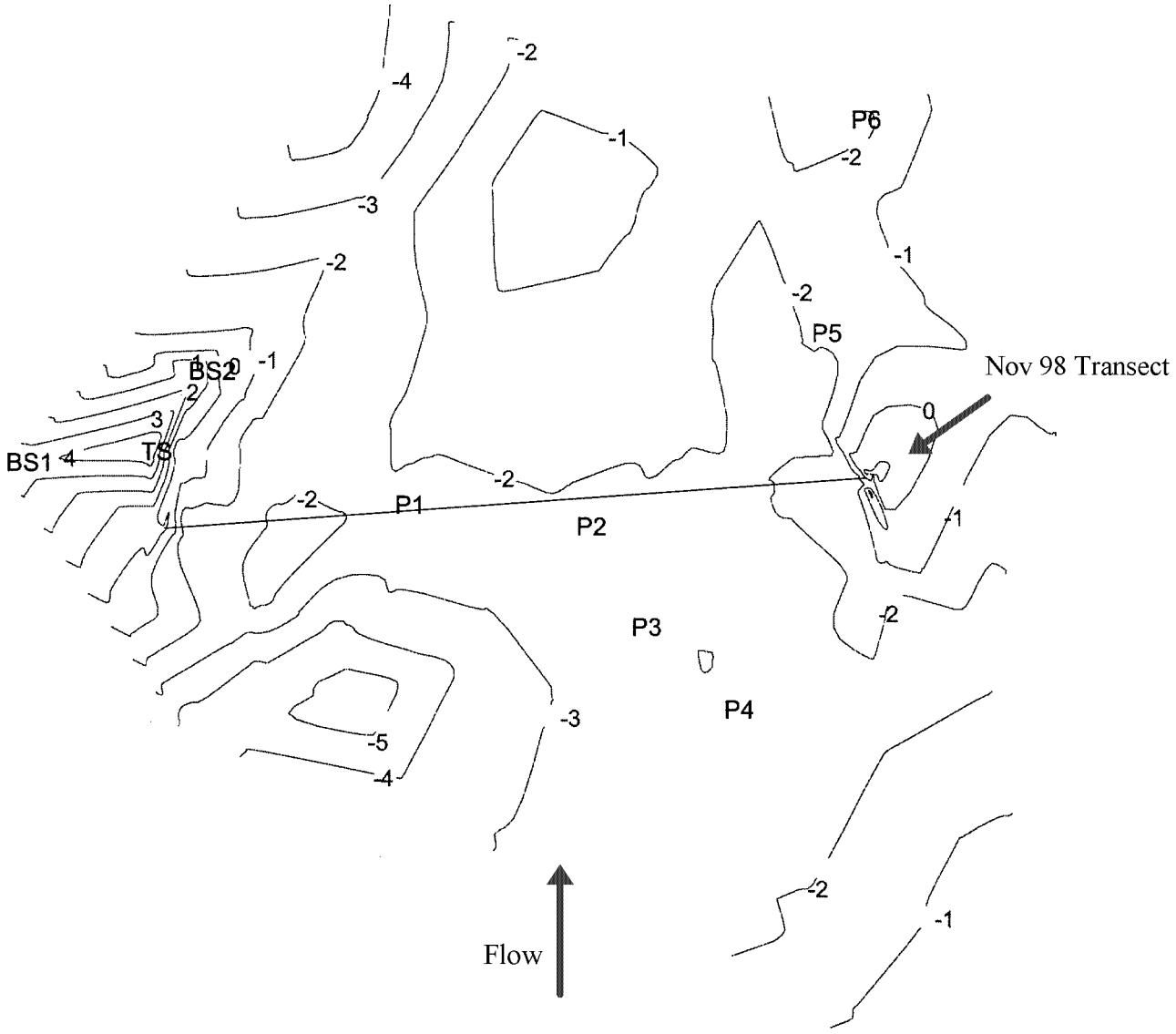

Figure 18. Contour map of Riffle R14 at rivermile 52.6 on the Stanislaus River on 12 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -0.3 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 3.58 feet and at back site 2 (BS2) is 1.81 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P6.

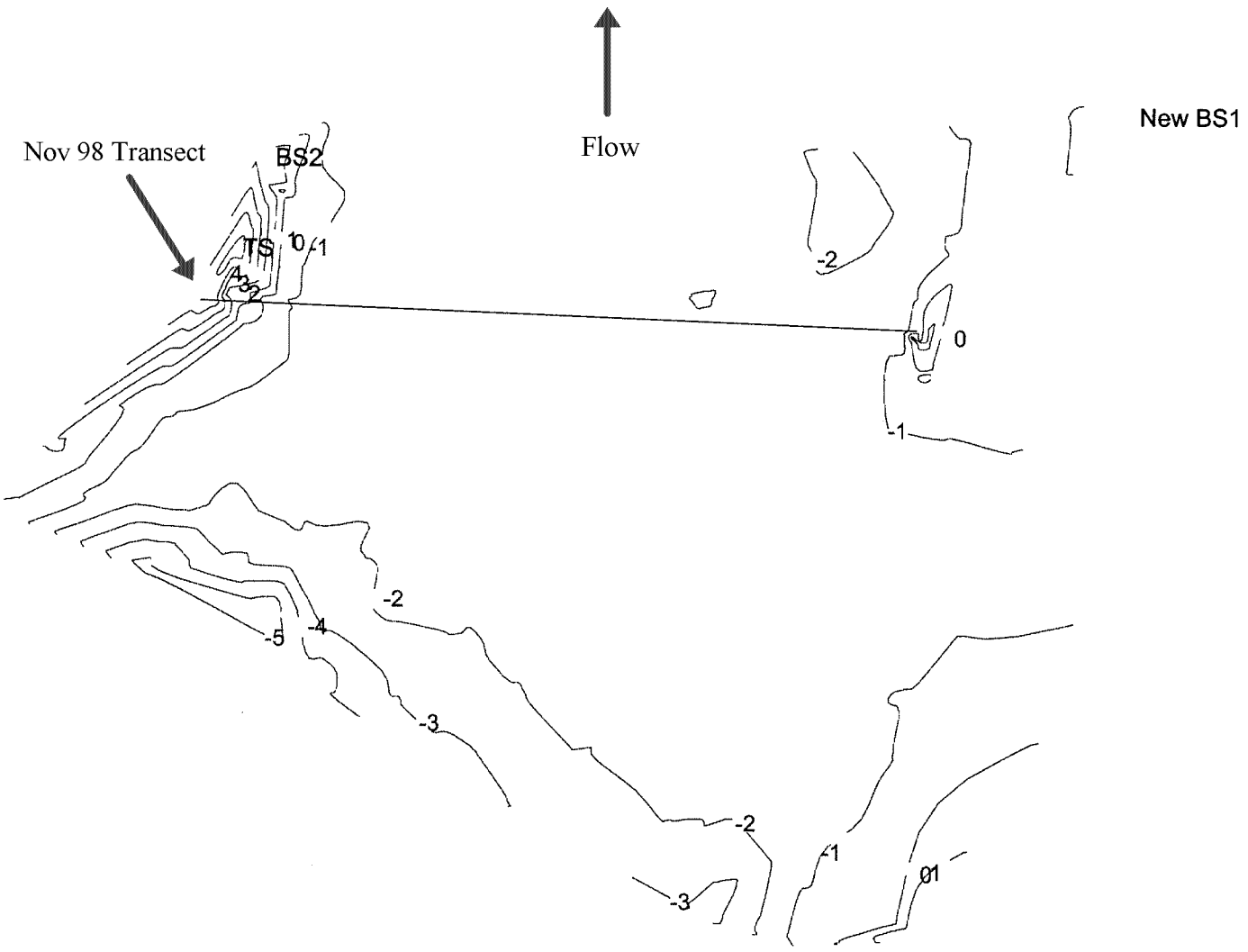

Figure 19. Contour map of Riffle R14 at rivermile 52.6 on the Stanislaus River on 27 September 1999, which was after 835 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -0.3 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at the new back site 1 (BS1) is 0.55 feet and at back site 2 (BS2) is 1.81 feet.

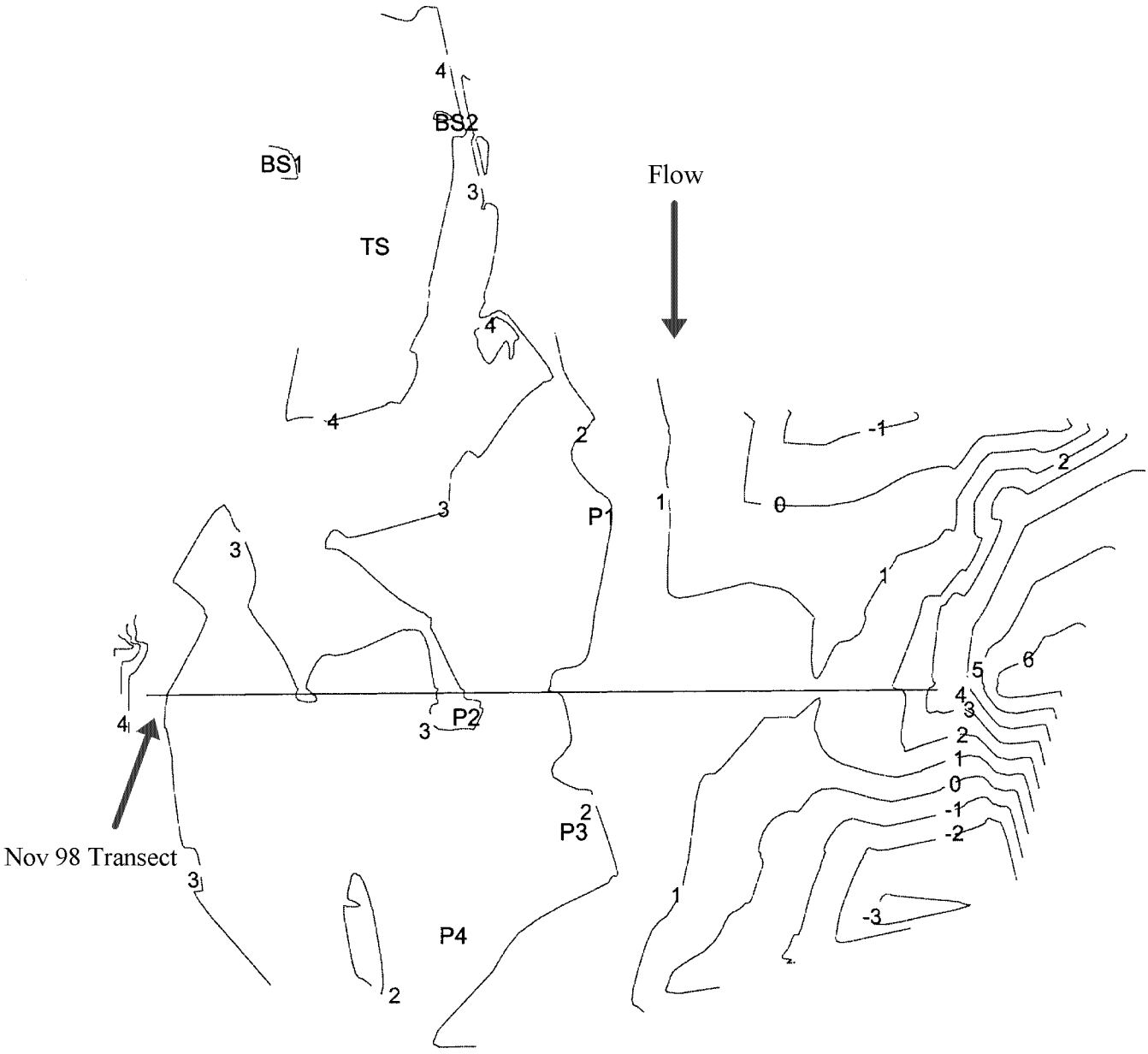

Figure 20. Contour map of Riffle R14A at rivermile 52.57 on the Stanislaus River on 13 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about 3.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.07 feet and at back site 2 (BS2) is 5.02 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P4.

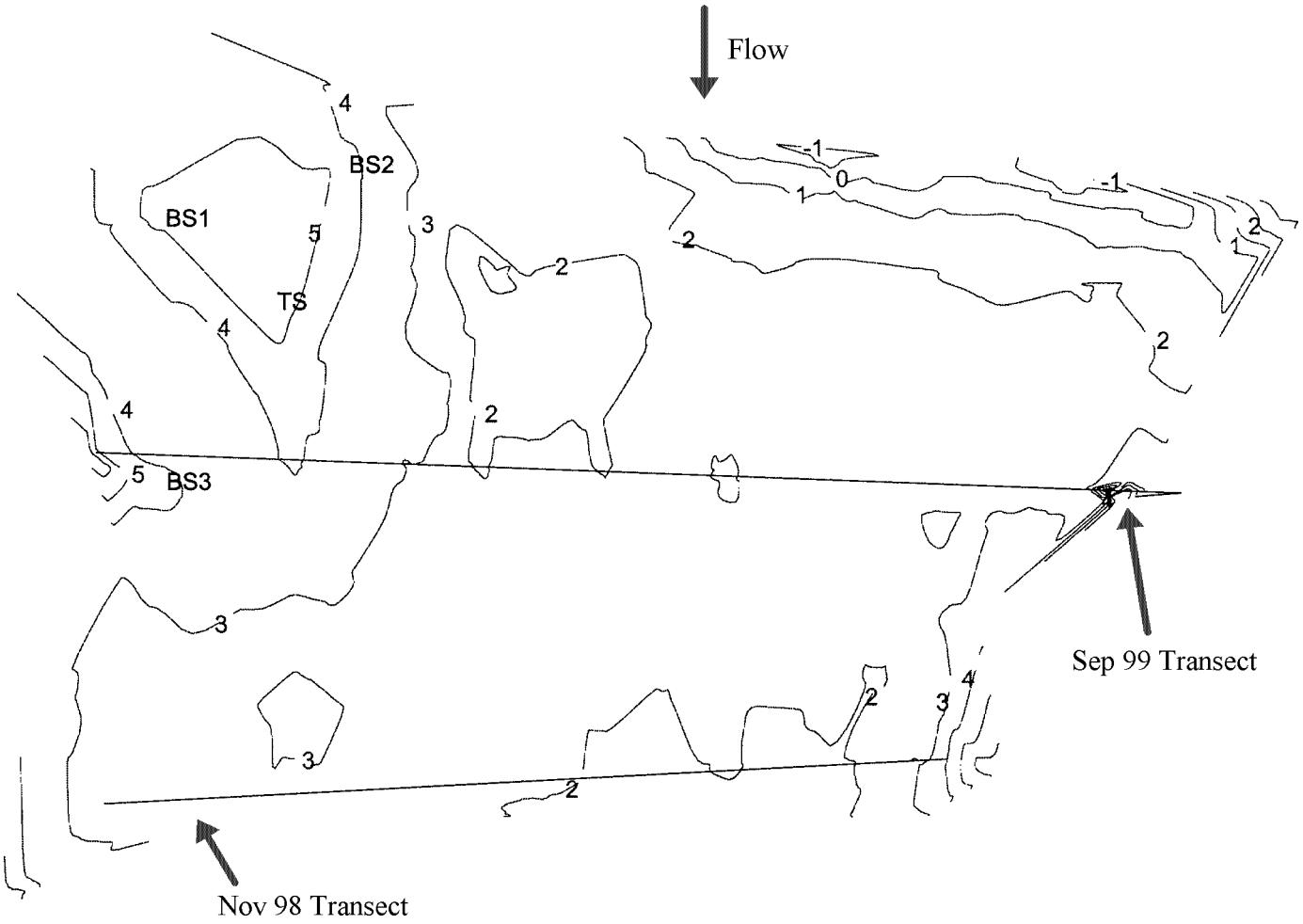

Figure 21. Contour map of Riffle R14A at rivermile 52.57 on the Stanislaus River on 23 September 1999, which was after 1,43 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about 3.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.07 feet and at back site 2 (BS2) is 5.02 feet.

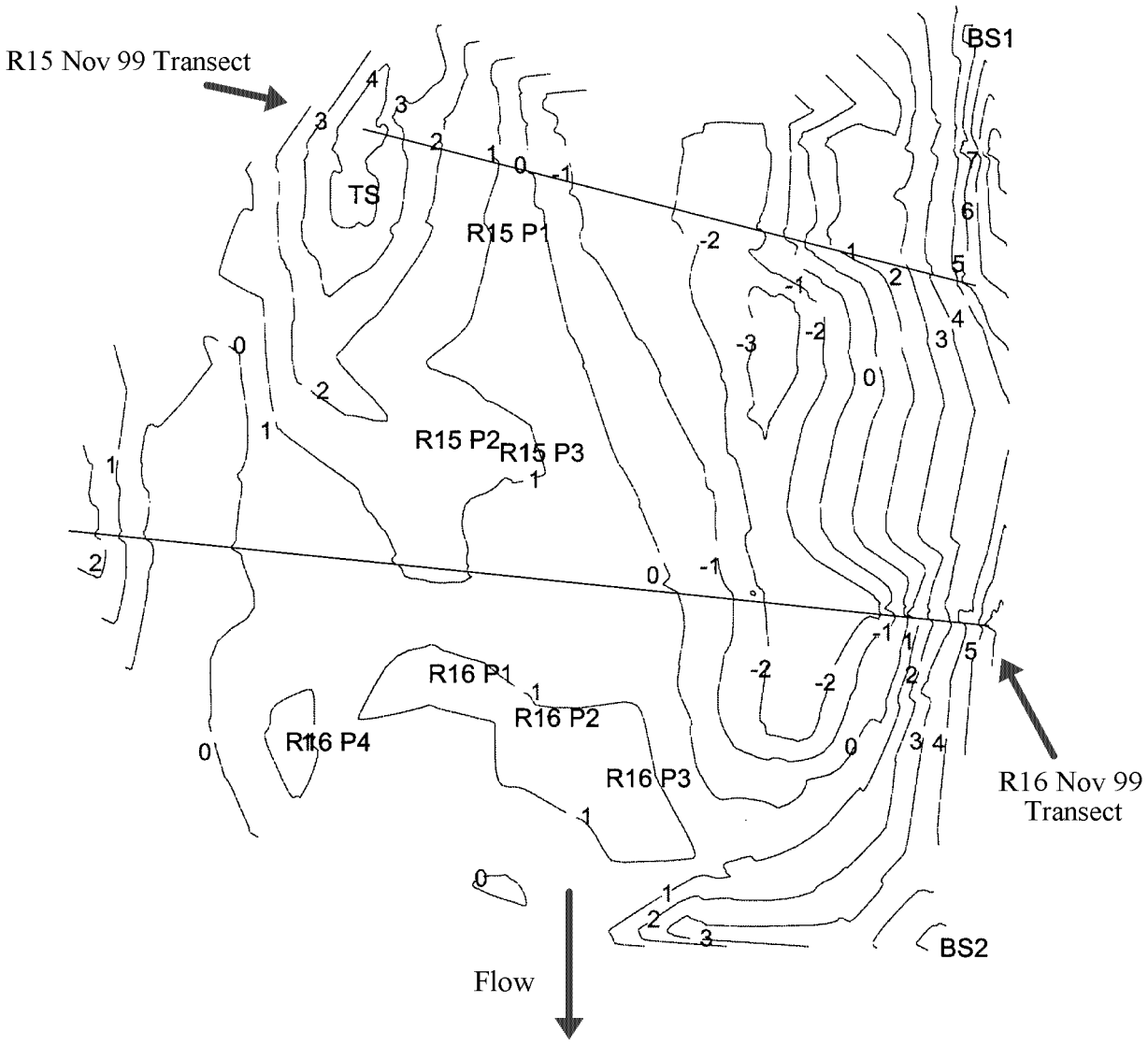

Figure 22. Contour map of Riffles R15 and R16 at rivermile 52.5 on the Stanislaus River on 10 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about 3.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.46 feet and at back site 2 (BS2) is 5.53 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P4.

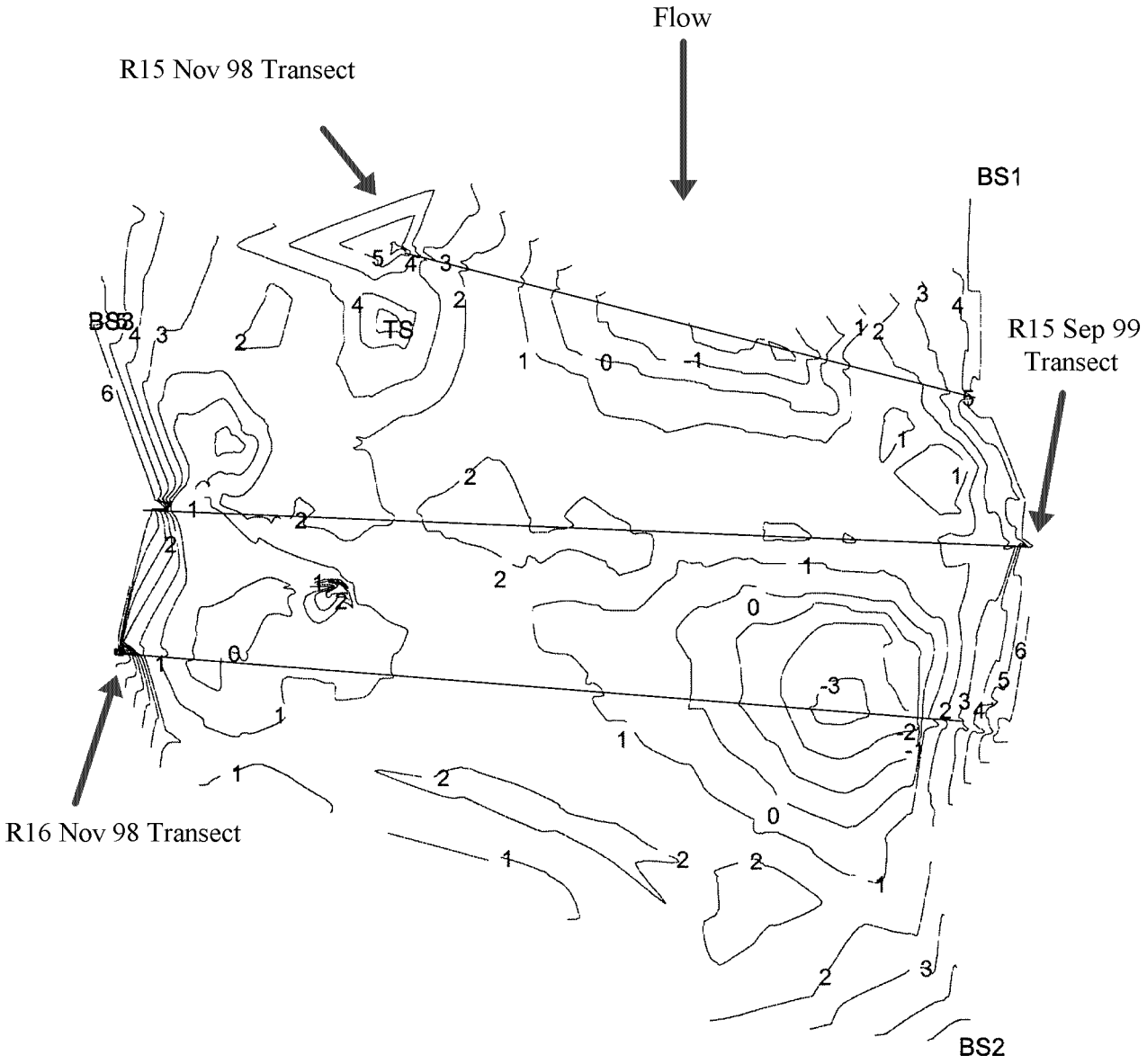

Figure 23 Contour map of Riffles R15 and R16 at rivermile 52.5 on the Stanislaus River on 23 September 1999, which was after 860 tons of gravel were added to R15 and 330 tons were added to R16. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about 3.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.46 feet and at back site 2 (BS2) is 5.53 feet.

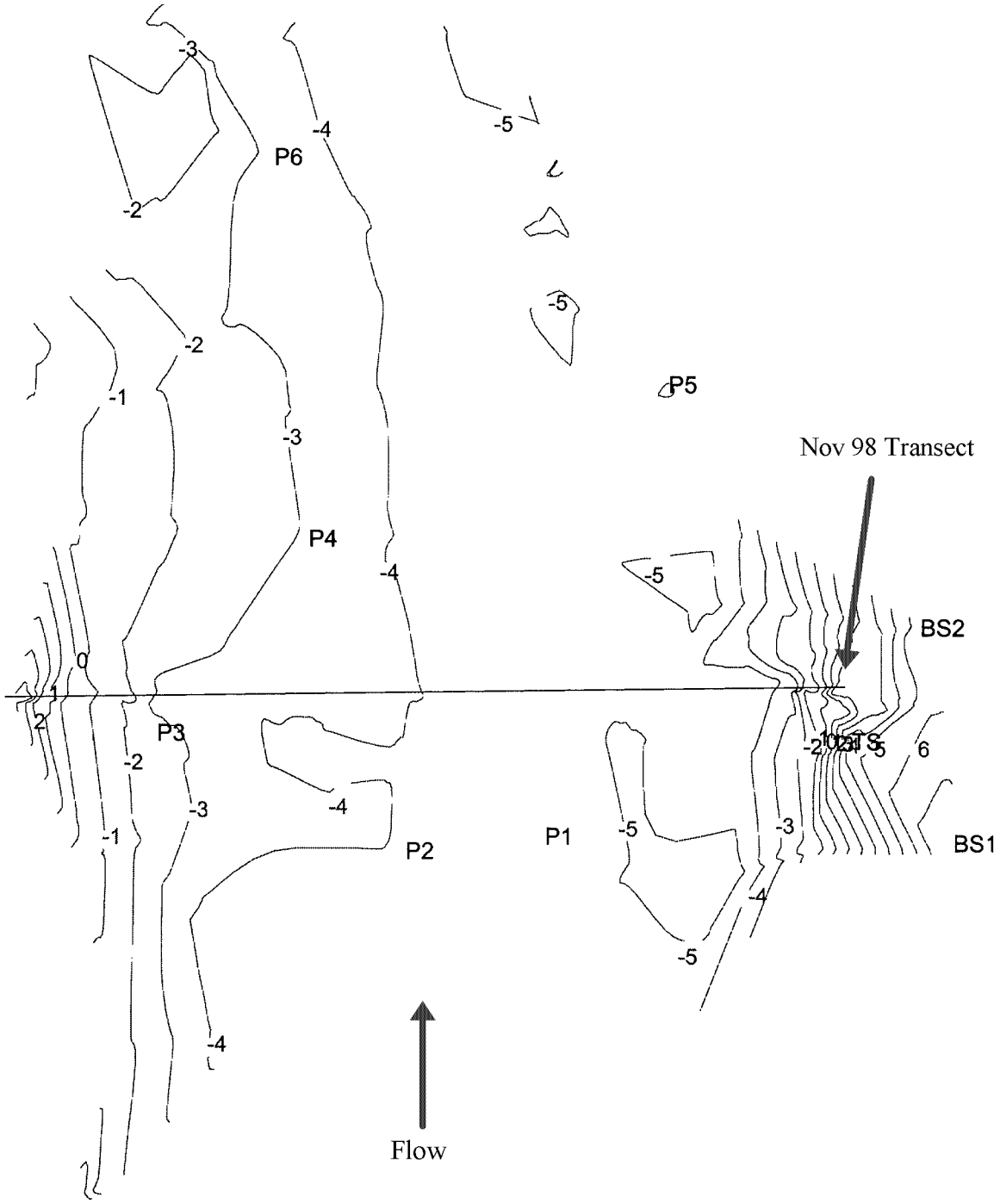

Figure 24. Contour map of Riffle R19 at rivermile 52.13 on the Stanislaus River on 13 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -1.9 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 7.93 feet and at back site 2 (BS2) is 5.16 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P6.

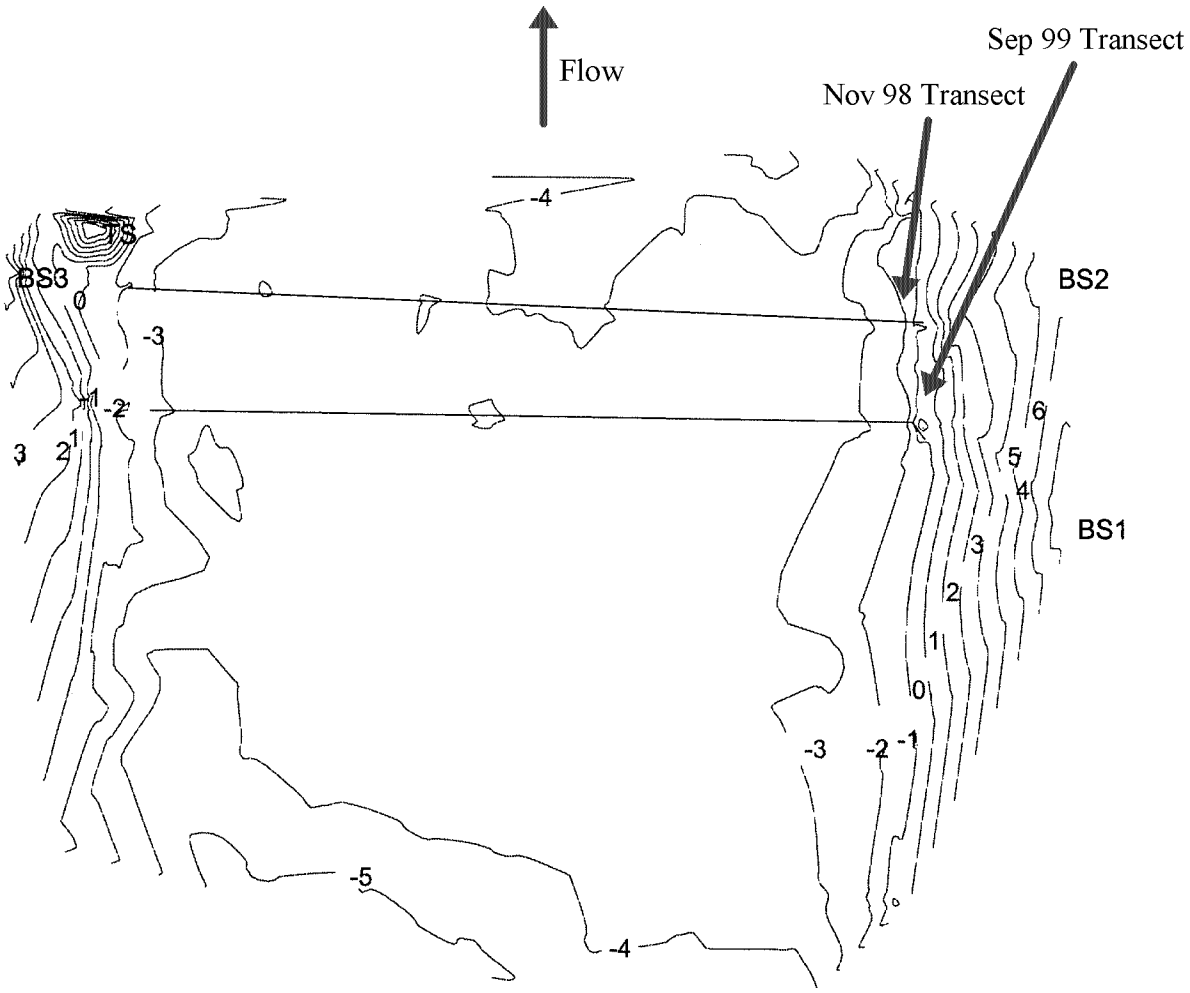

Figure 25. Contour map of Riffle R19 at rivermile 52.13 on the Stanislaus River on 27 September 1999, which was after 675 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -1.9 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 7.93 feet and at back site 2 (BS2) is 5.16 feet.

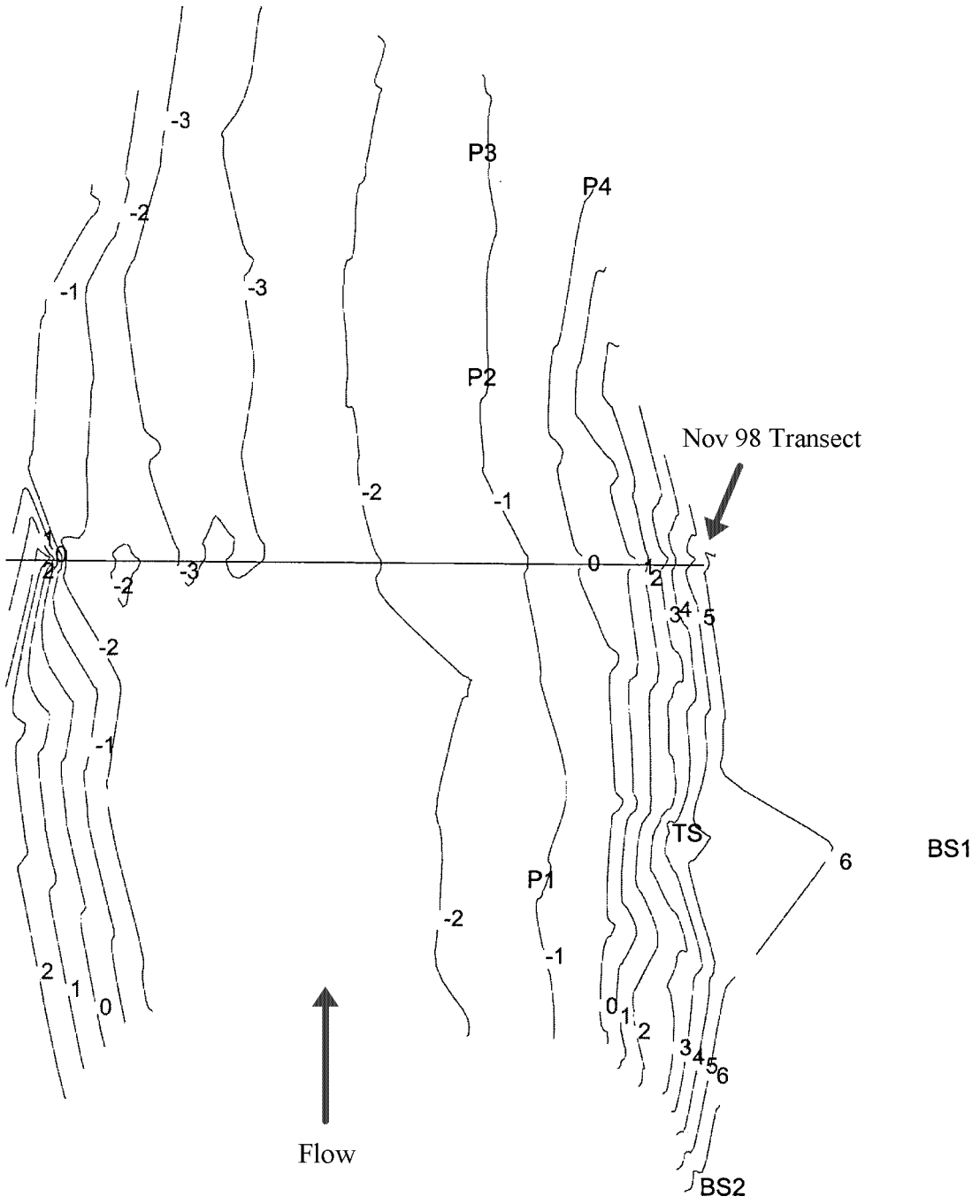

Figure 26. Contour map of Riffle R19A at rivermile 52.06 on the Stanislaus River on 18 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about 2.4 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 6.77 feet and at back site 2 (BS2) is 7.66 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P4

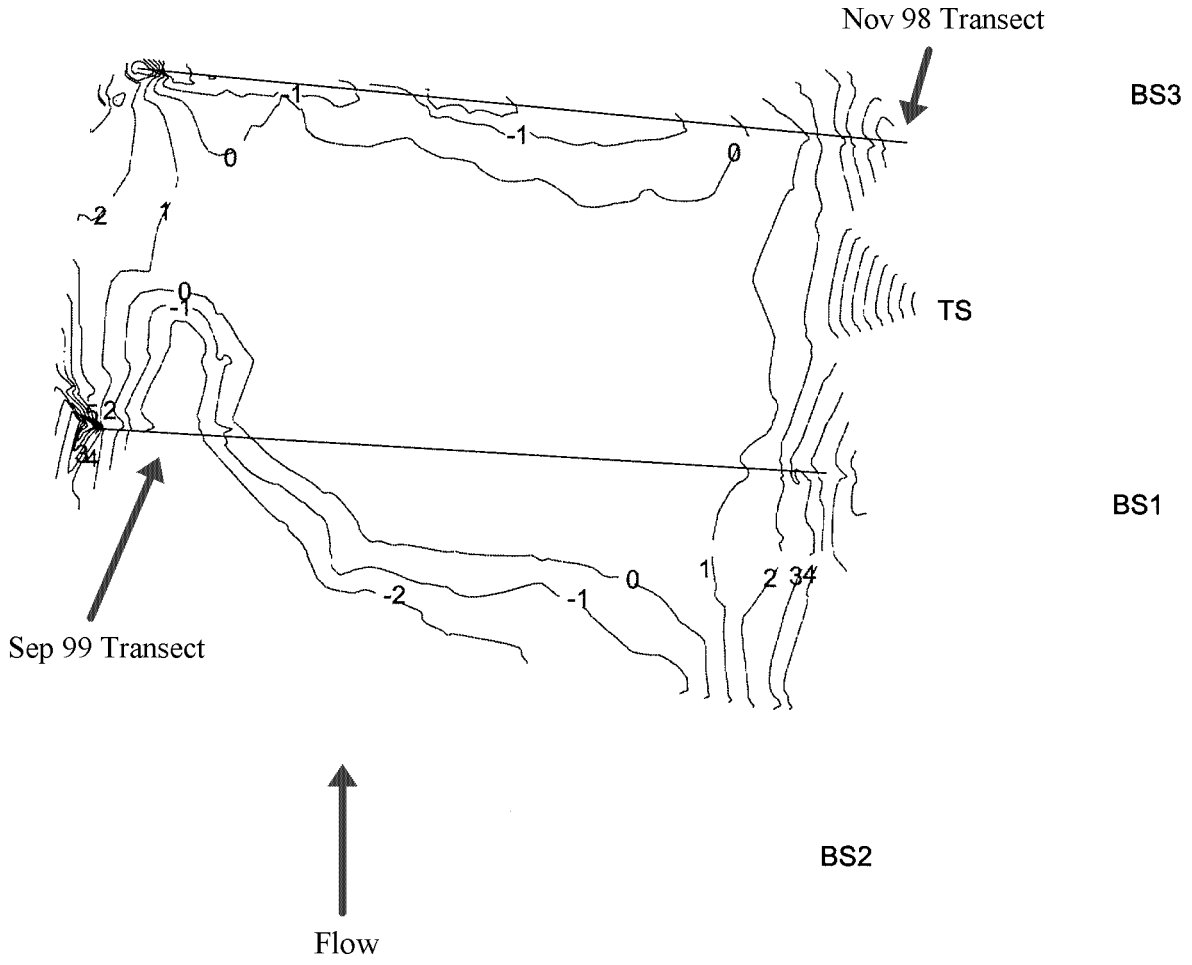

Figure 27. Contour map of Riffle R19A at rivermile 52.06 on the Stanislaus River on 28 September 1999, which was after 950 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about 2.4 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 6.77 feet and at back site 2 (BS2) is 7.66 feet.

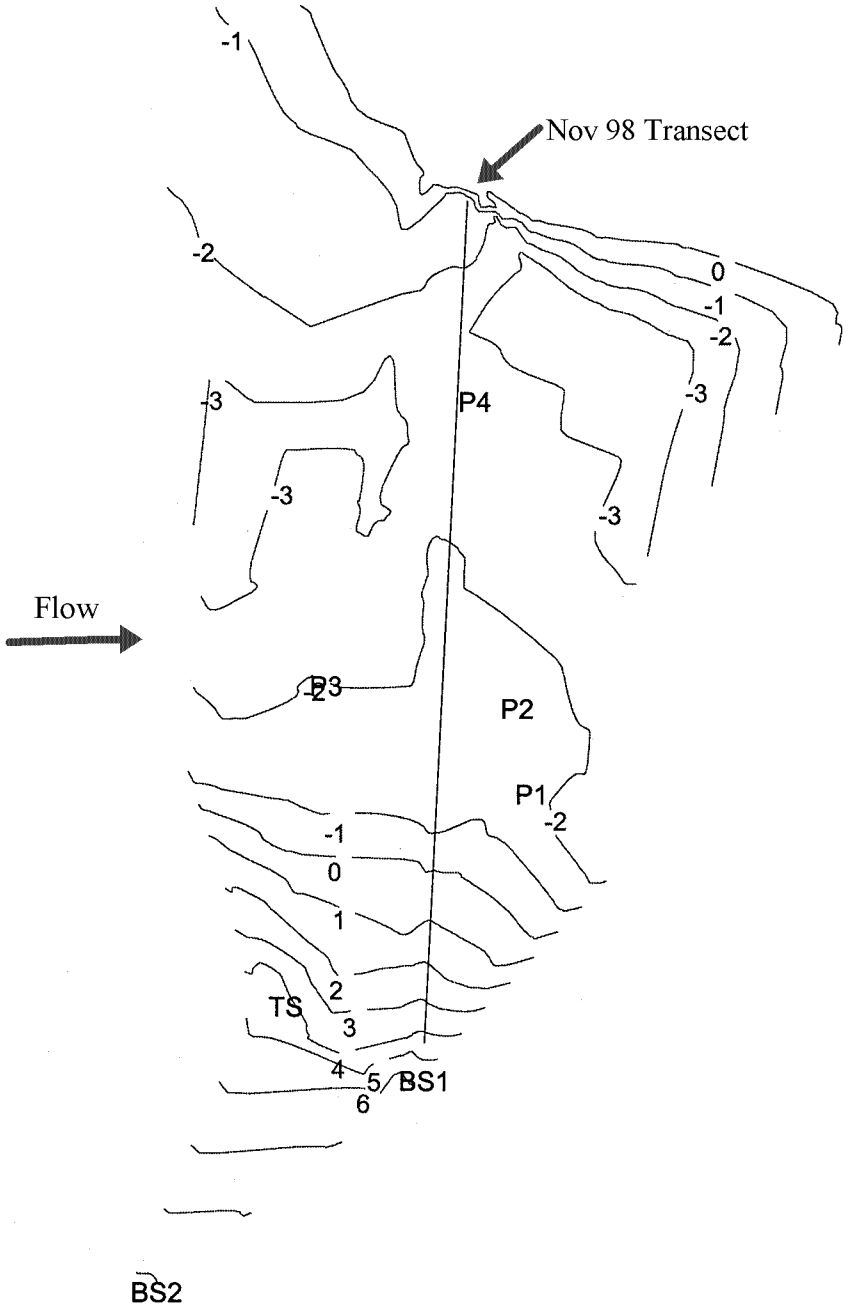

Figure 28. Contour map of Riffle R28A at rivermile 50.2 on the Stanislaus River on 6 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 1.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 6.29 feet and at back site 2 (BS2) is 9.26 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P4

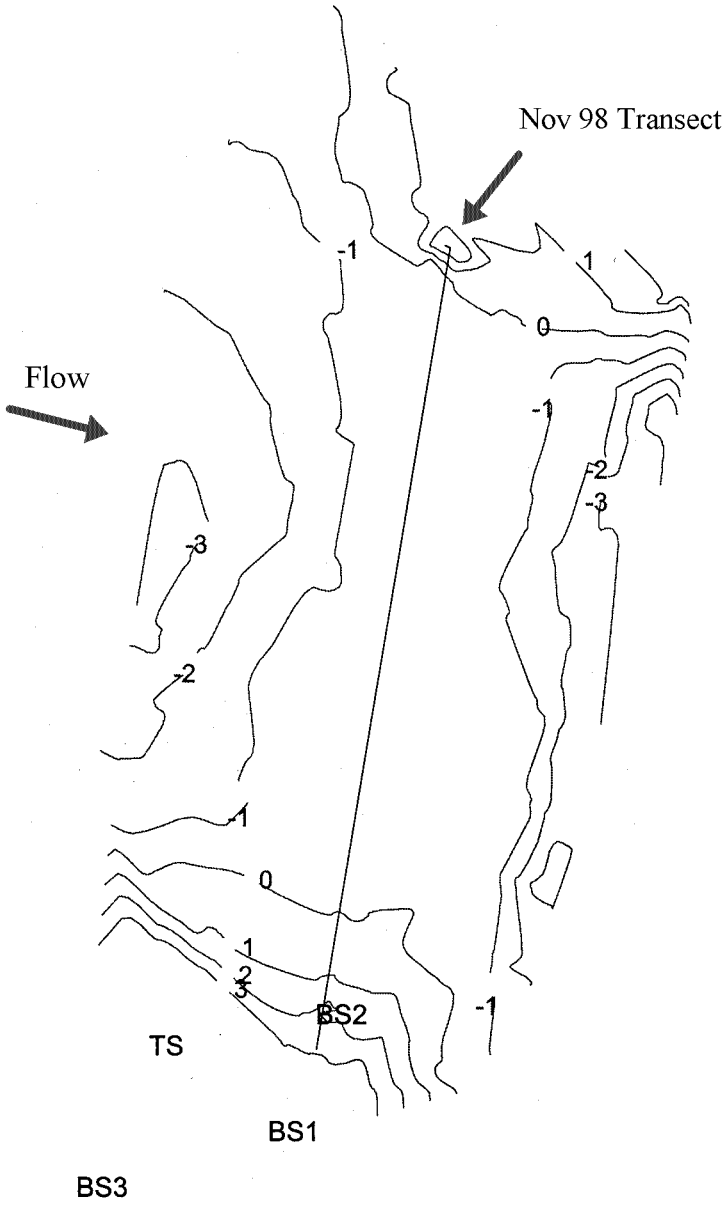

Figure 29. Contour map of Riffle R28A at rivermile 50.2 on the Stanislaus River on 28 September 1999, which was after 450 tons were added. The contours are in one-foot intervals and the scale is one inch equals 25.0 feet. The water surface elevation was about 1.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 6.29 feet, at the new back site 2 (BS2) is 2.03 feet, and at back site 3 (BS3) is 10.90 feet.

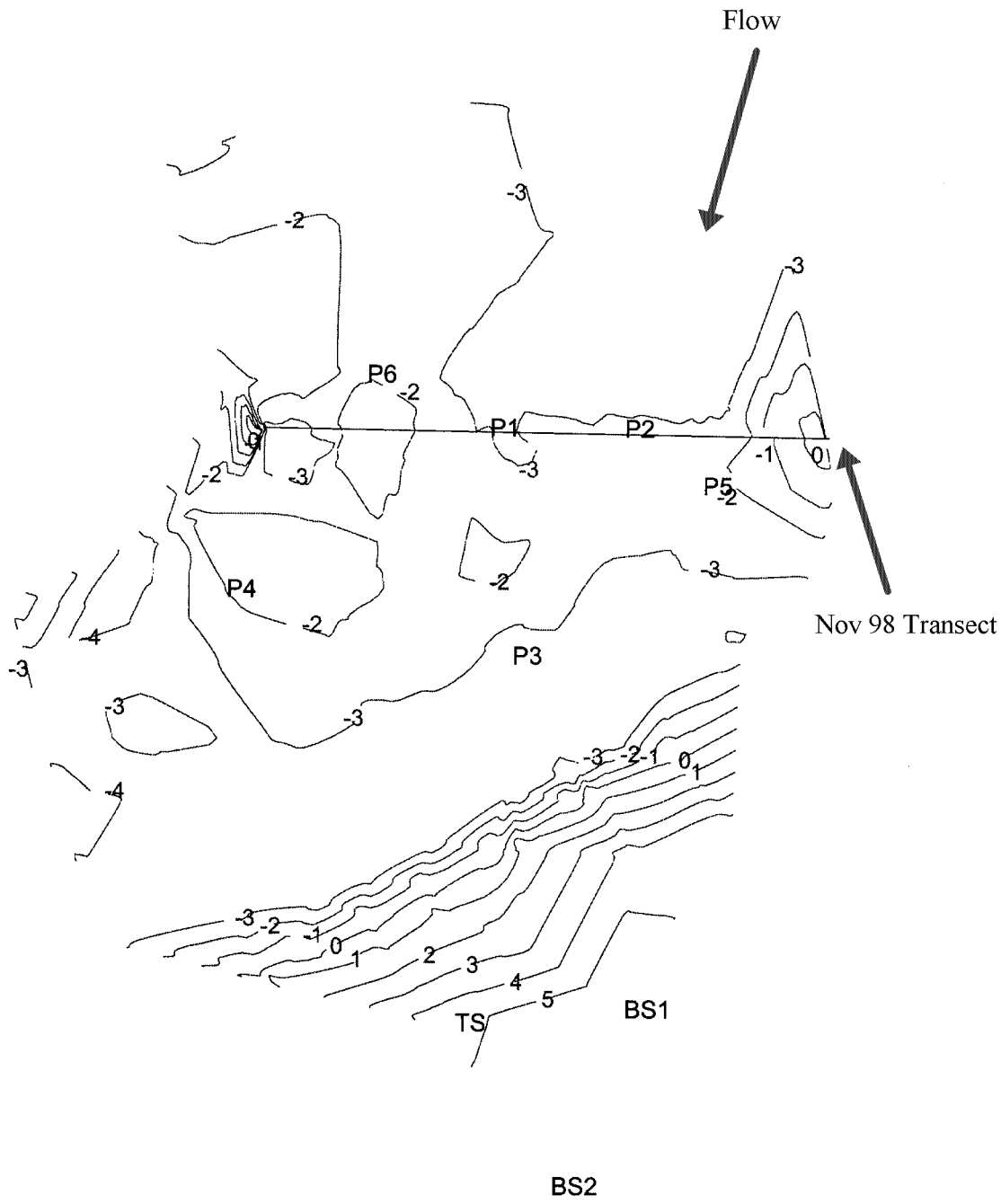

Figure 30. Contour map of Riffle R29 at rivermile 49.75 on the Stanislaus River on 9 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -0.4 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.82 feet and at back site 2 (BS2) is 5.68 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P6.

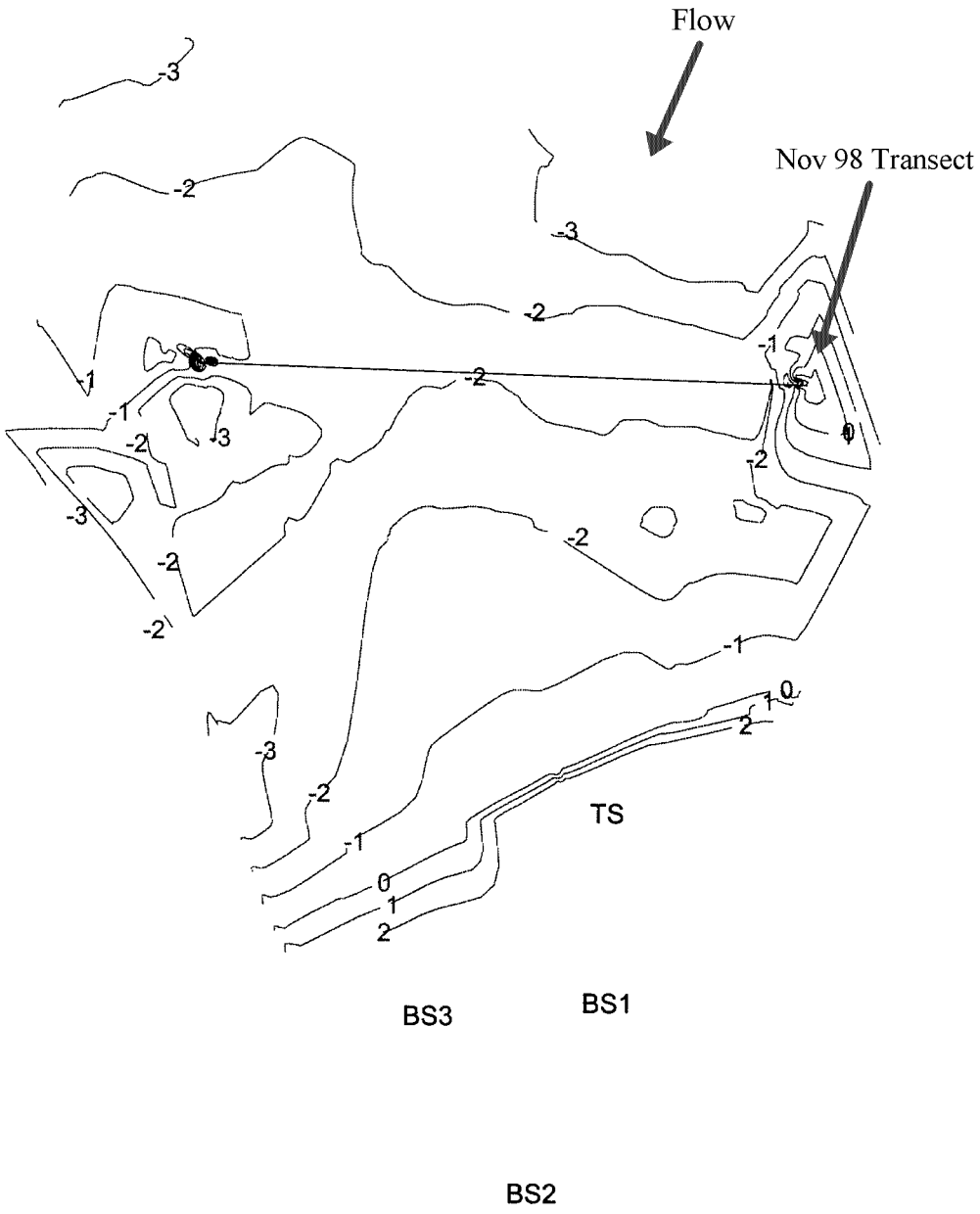

Figure 31. Contour map of Riffle R29 at rivermile 49.75 on the Stanislaus River on 30 September 1999, which was after 300 tons of gravel was added. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -0.4 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 5.82 feet and at back site 2 (BS2) is 5.68 feet.

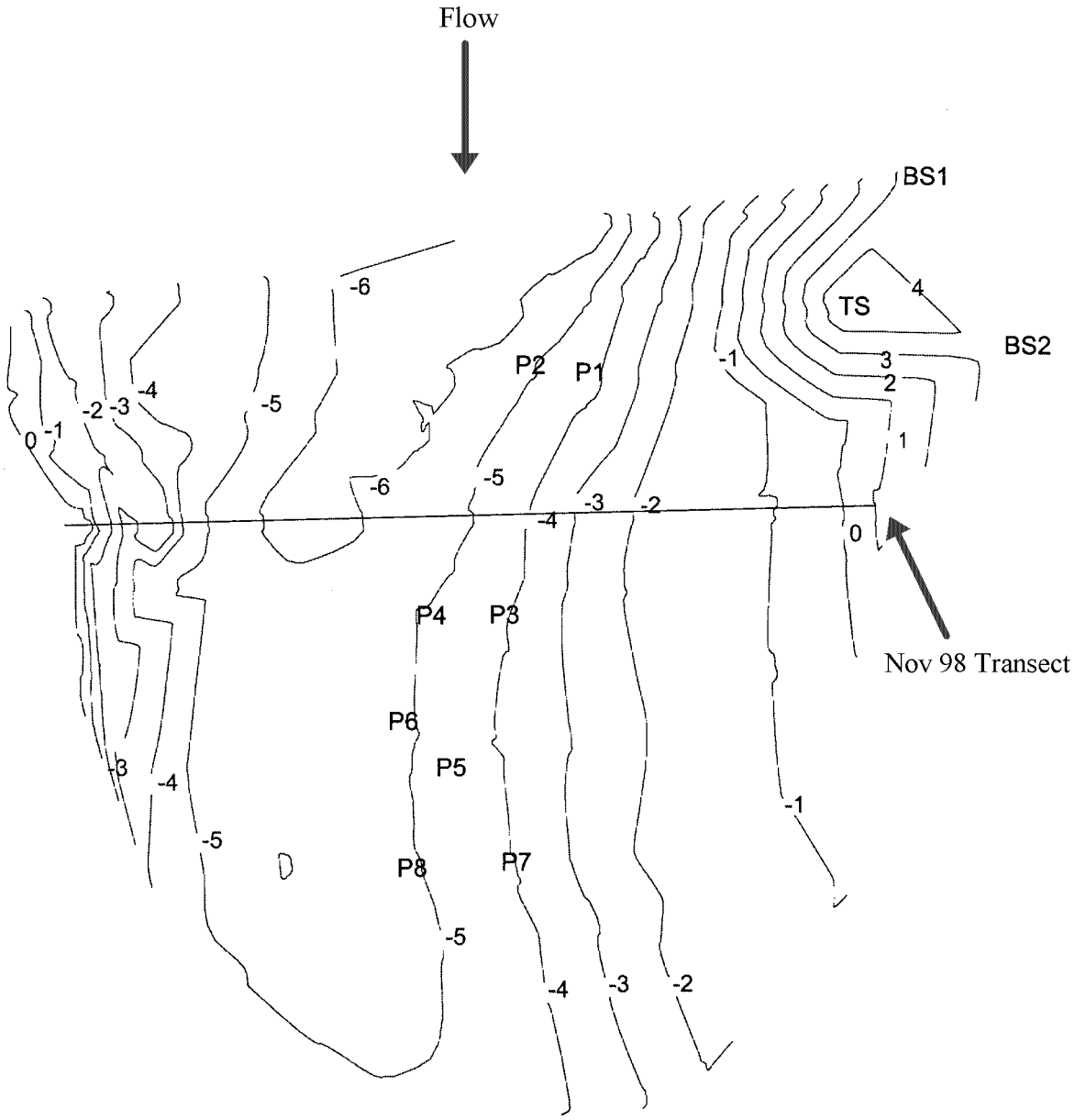

Figure 32. Contour map of Riffle R43 at rivermile 46.9 on the Stanislaus River on 2 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -2.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 3.17 feet and at back site 2 (BS2) is 3.70 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P8.

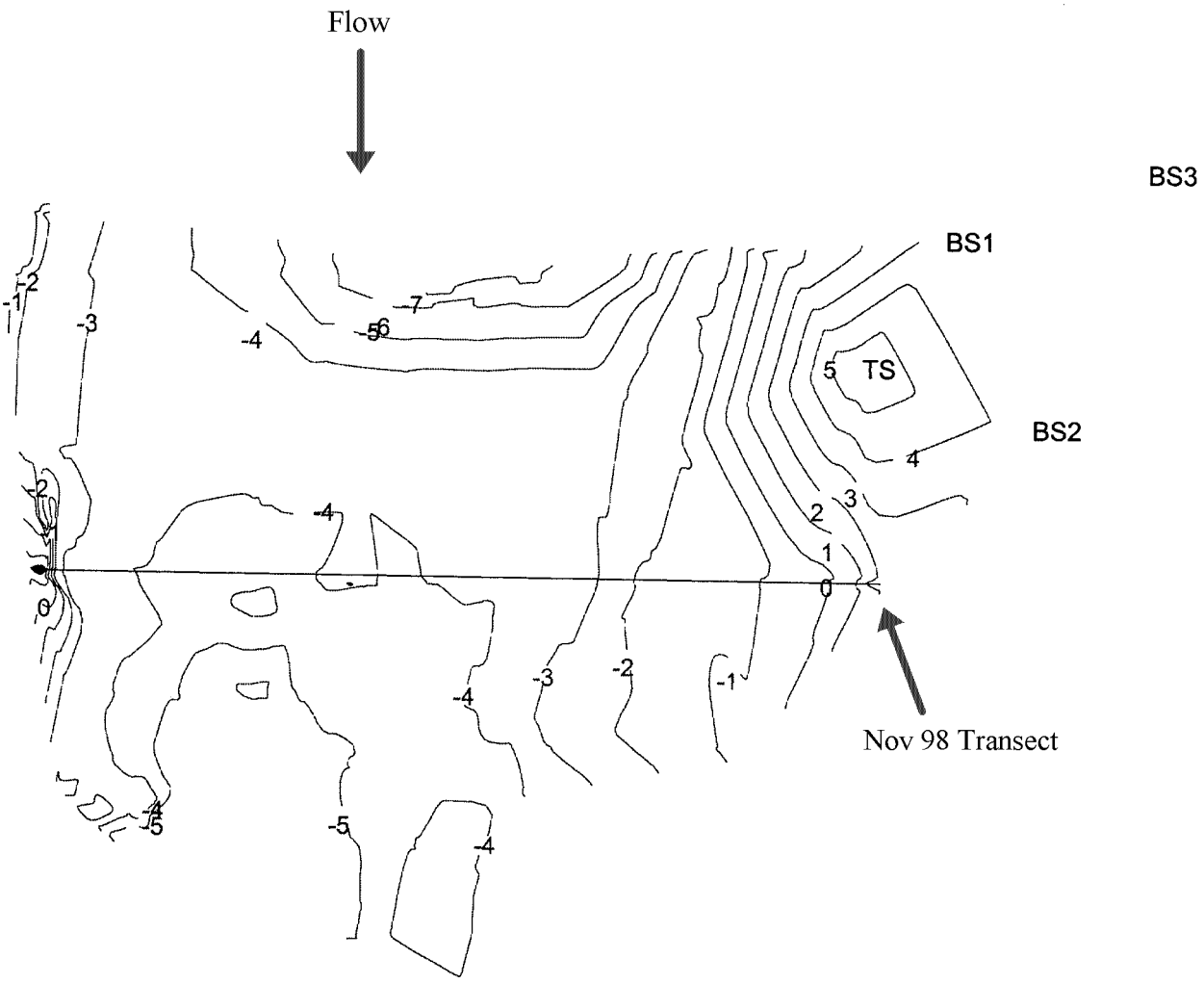

Figure 33. Contour map of Riffle R43 at rivermile 46.9 on the Stanislaus River on 28 September 1999, which was after 440 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 29.2 feet. The water surface elevation was about -2.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 3.17 feet and at back site 2 (BS2) is 3.70 feet.

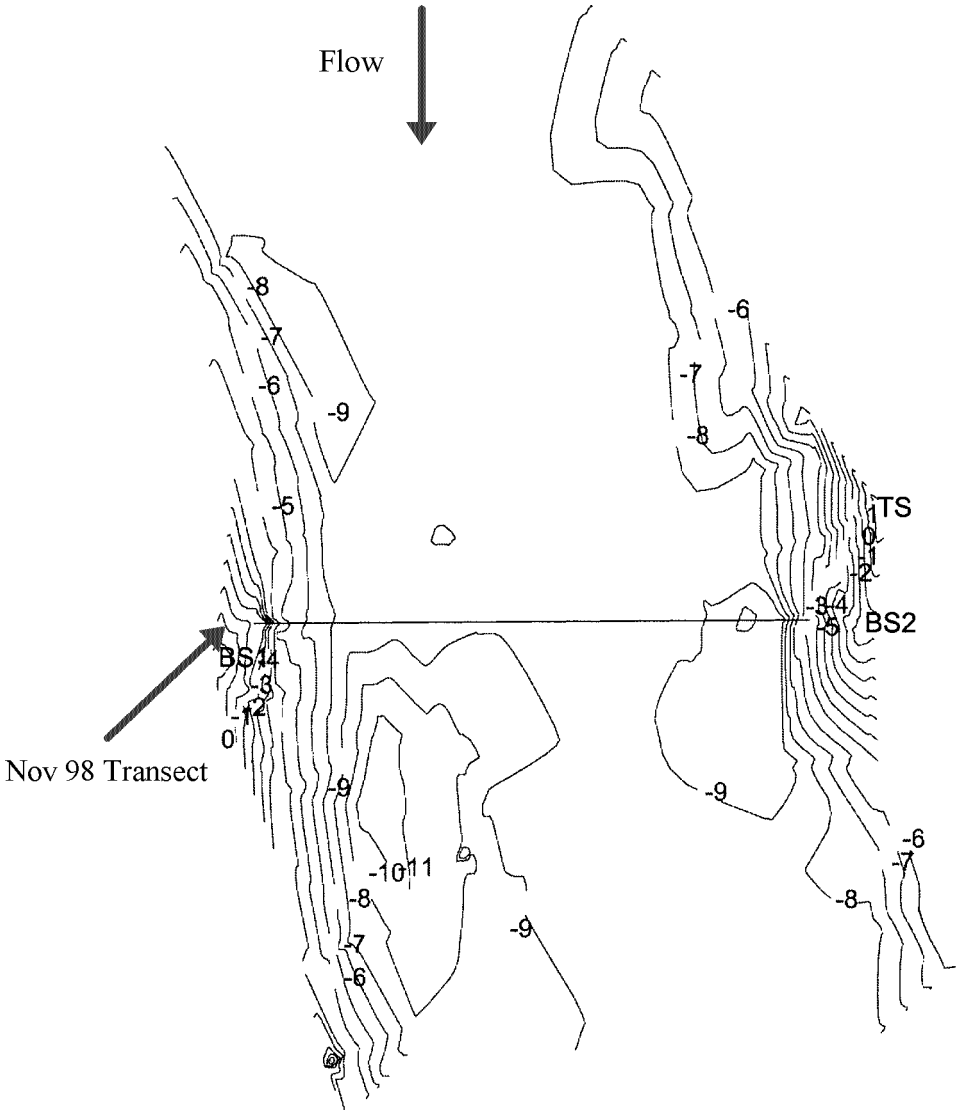

Figure 34. Contour map of Riffle R57 at rivermile 44.6 on the Stanislaus River on 17 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -5.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 2.72 feet and at back site 2 (BS2) is 1.60 feet. No substrate or intragravel water quality samples were collected because the water was too deep.

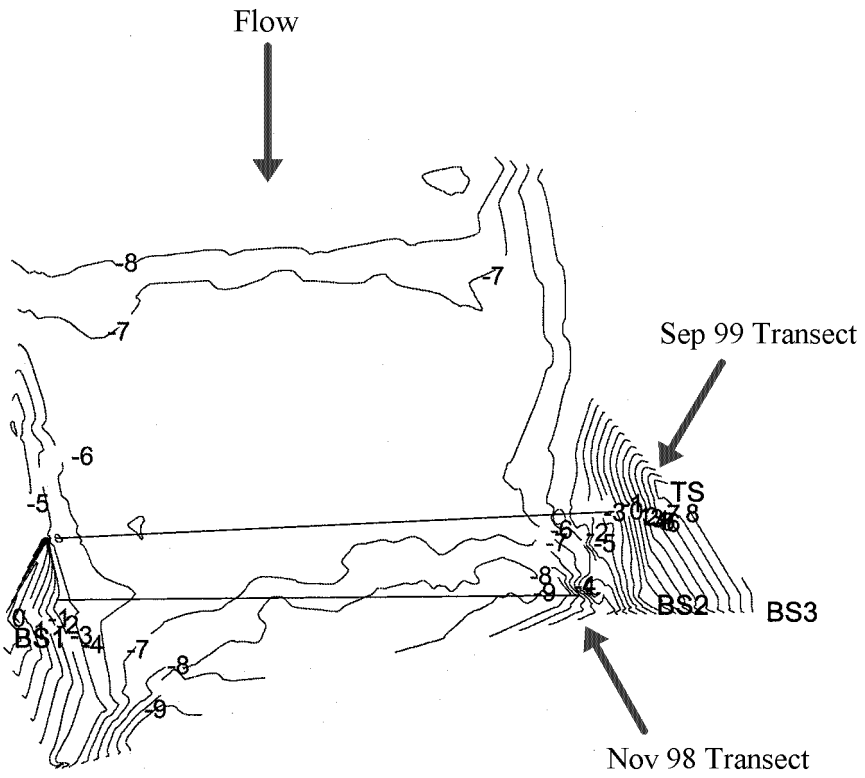

Figure 35. Contour map of Riffle R57 at rivermile 44.6 on the Stanislaus River on 29 September 1999, which was after 900 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 33.3 feet. The water surface elevation was about -5.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 and Sep 99 transects and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 2.72 feet and at back site 2 (BS2) is 1.60 feet.

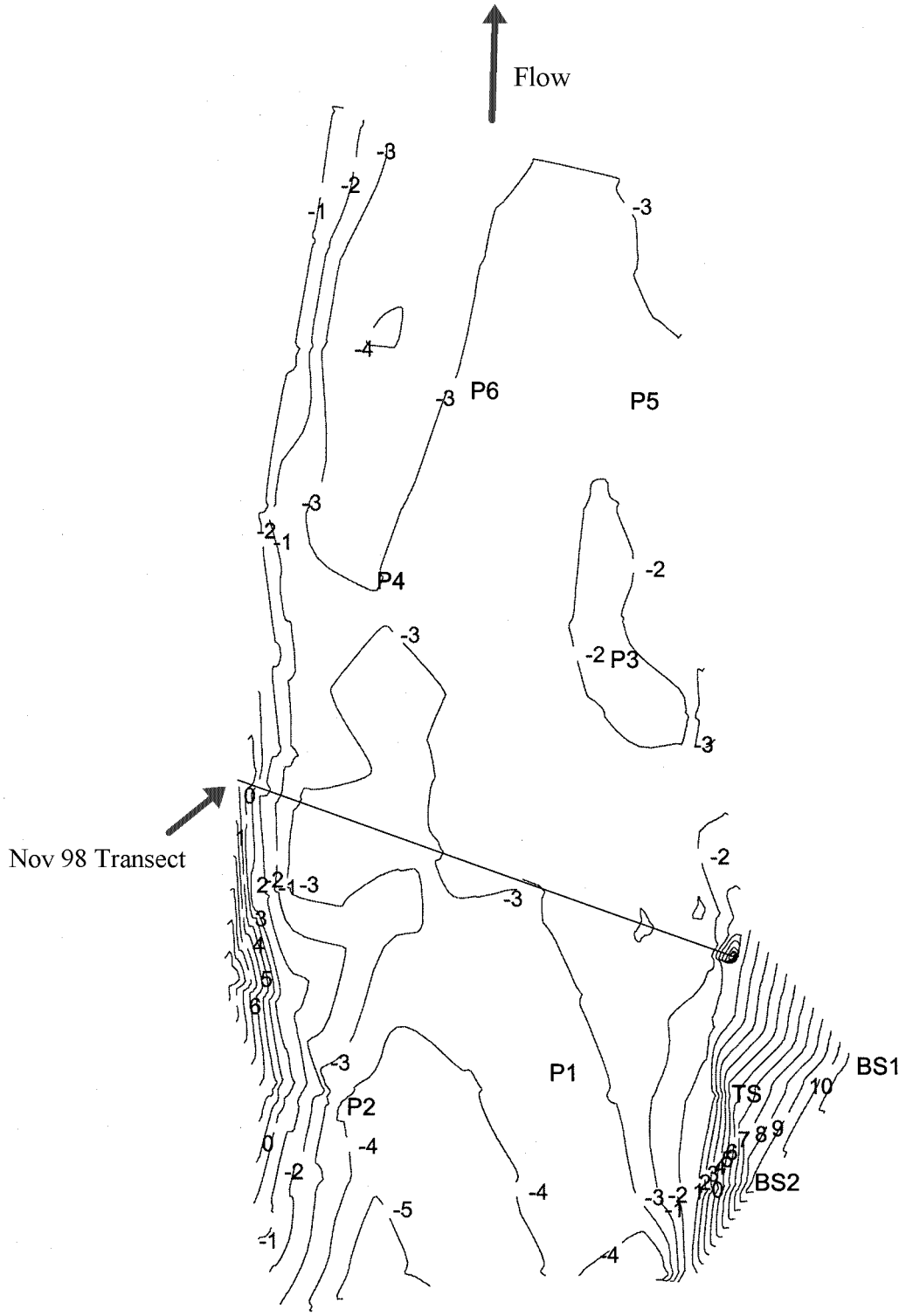

Figure 36. Contour map of Riffle R58 at rivermile 44.5 on the Stanislaus River on 17 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 37.5 feet. The water surface elevation was about -0.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 11.87 feet and at back site 2 (BS2) is 9.25 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P6.

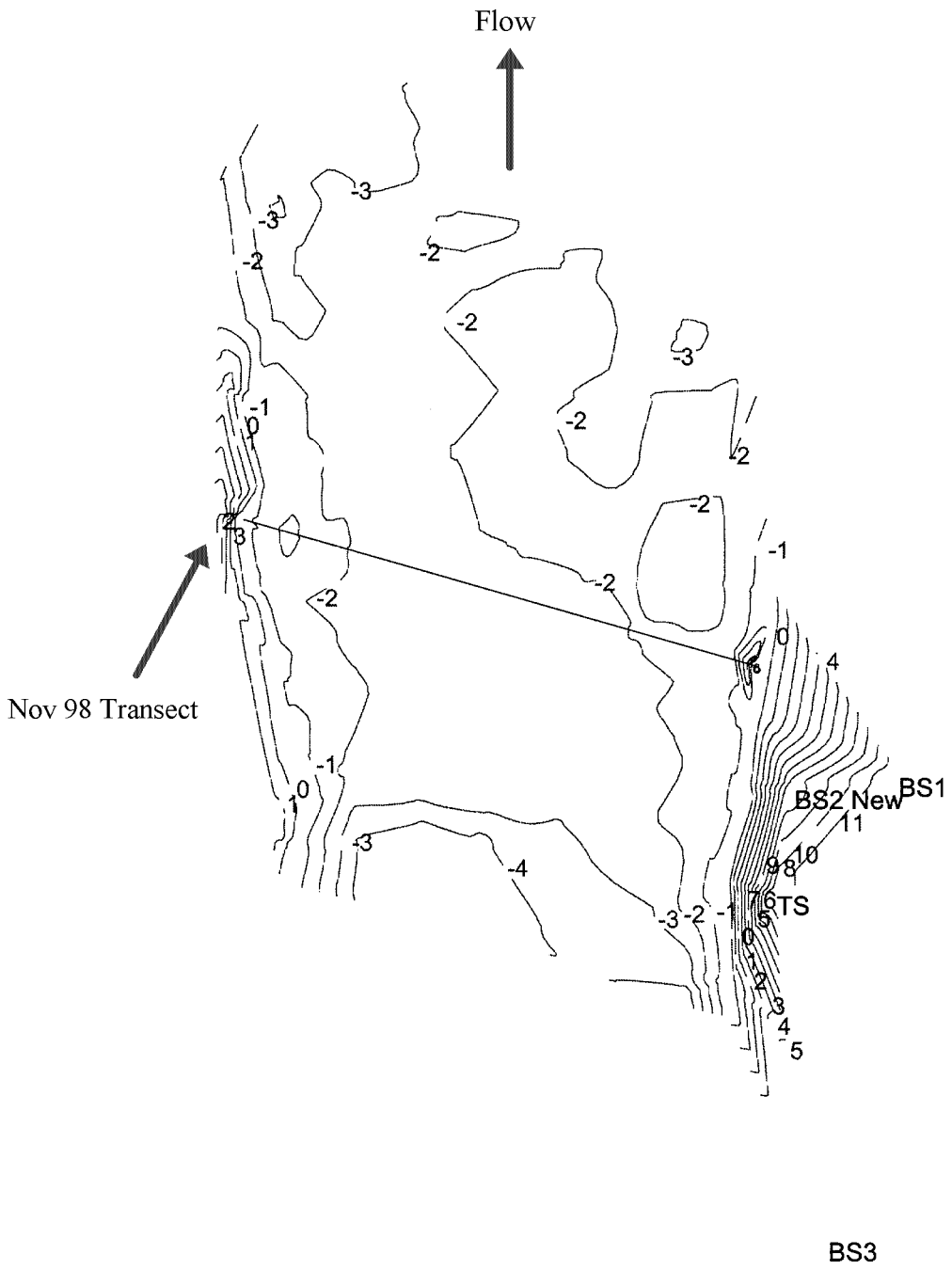

Figure 37. Contour map of Riffle R58 at rivermile 44.5 on the Stanislaus River on 29 September 1999, which was after 840 tons of gravel were added. The contours are in one-foot intervals and the scale is one inch equals 37.5 feet. The water surface elevation was about -0.6 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is 11.87 feet, at the new back site 2 (BS2) is 7.43 feet, and at back site 3 (BS3) is 9.22 feet.

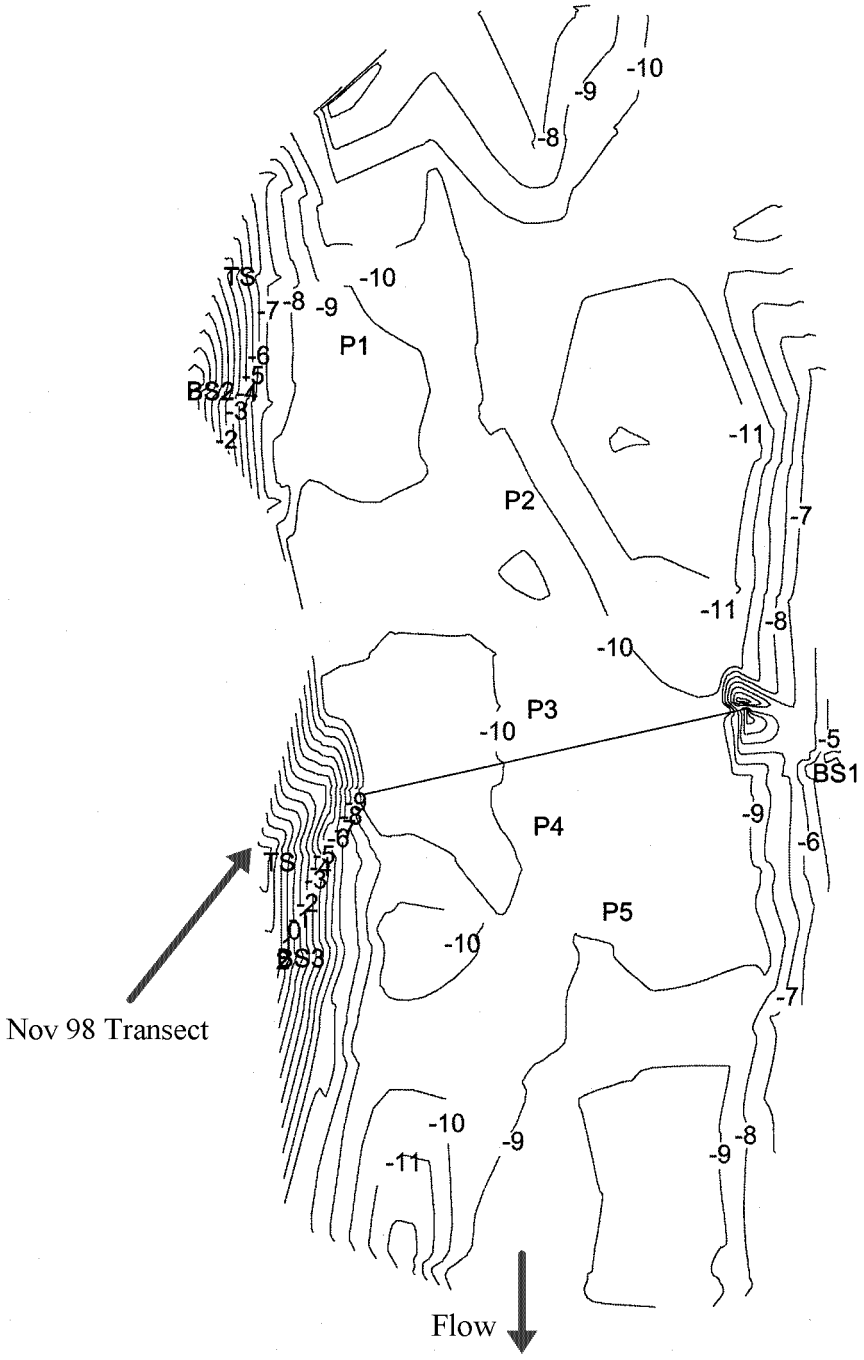

Figure 38. Contour map of Riffle R78 at rivermile 40.2 on the Stanislaus River on 16 August 1999, which was prior to gravel addition. The contours are in one-foot intervals and the scale is one inch equals 37.5 feet. The water surface elevation was about -7.0 feet. Elevation measurements were made with a total station (TS) at 5 foot-intervals along the Nov 98 transect and elsewhere in a grid pattern with approximately 15-foot spacing. The elevation of the top of the metal pins at back site 1 (BS1) is -4.28 feet, at back site 2 (BS2) is 3.74 feet, and at back site 3 is 2.77 feet. Substrate and intragravel water quality samples were collected at the sites marked P1 through P5.